HYDRAULIC

ITS PROPERTIES,

AND USE

BY

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PREFACE TO

THE following pages co
study of the nature and p
and the various methods
are in use, for testing ceme

The subject is not so s
casual observer, but abou
results of experiments and
authorities, which at times

The views of the auth

and concrete, and a numbe
appended for the purpose o
of leading American enginee

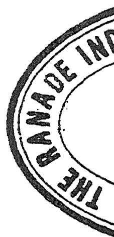
ITHACA, N. Y., March, 1897.

PREFACE TO SECO

IN this edition a general rev
been made with the purpose o
of the most recent investigation
position and properties of cem
the latest standard methods of c

The articles relating to the con
been practically rewritten, while
of cement have been thoroughly r

The specifications appended



CONTE

CHAPT

HYDRAUL

CHAPTER I

THE SETTING AND HARDEN

CHAPTER I

THE SOUNDNESS OF

TESTS FOR THE STR

CHAPTE

TESTS FOR S

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SPECIAL

CHAPTER

CEMENT MORTAR AN

APPENDIX

SPECIFICATIONS FOR THE REC

HYDRAULI

CHAP

HYDRAU

ART. 1. I

LIME is the name comm
obtained by the calcinatio
stones employed differ grea
properties of the limes obt
the nature and proportions
in them.

When the limestone is c
bonate of lime, the clinker
known as *quicklime*, possesses
or *slaking*, upon being treat
of water. The slaking of li
tion when in contact with wa
panied by a considerable in
mass of lime and by a rise i
tity of water be only sufficie
the lime, the quicklime is red
if the water be in excess it b

The slaked lime thus f

property, when mixed to a pa
to stand in the air, of hard
to any surface with which it
hardening of common limes
exposed to the air and allowe

When lime is nearly pur
great it is known as *fat lim*

If the lime have mixed c
considerable percentages of i
acter, which act as an adulte
of the lime, causing a partial lo
and also diminishing its powe
as *meagre lime.*

When the impurities in the
of silica and alumina, they n
stroying its property of slakin
hardening under water and c
to the presence of air.

When the proportions of
are such that the material

ing products differ greatly ...
affected both by the composi...
and by the manipulation give...
of manufacture. Because of ...
acter of the material, it is extr...
any general laws governing its ...
system of testing which shall g...
tion of value.

Hydraulic limes are used quit...
are not made to any extent in ...
can cement industry is, howe...
Natural cements are manufactu...
and the production of Portland...
to large proportions, althoug...
foreign cement is still importe...

Art. 2. Chemica...

The most important ingre...
stones, in addition to the carb...
alumina, silica, oxide of ir...
commonly contain also smal...
acid, phosphoric acid, oxid...
soda, bituminous or carbonac...
stances, and water. The lim...
contain small particles of cind...
employed.

The volatile substances are...
lime because they disappear ...
centage of carbonic acid and ...

driven off in the burning or is a
the air will appear in the lime. I
acid be large, it indicates eithe
been incomplete or that the lim
by subsequent exposure. The
thus diminished, the portion of l
the carbonic acid being rendered

Silica is undoubtedly the mo
rendering lime hydraulic and is
in the form of silicious sand no
unaffected by the burning and r
in the product. It is only that p
is present in a condition to be
and combine with the lime which
hydraulic properties to the lime.

Alumina is an important ele
although not, as seems to be the c
tial to its hydraulicity. Vicat fo
out silica would not render

ditions under which it is present
in most cases is in considera
hydraulic limes by burning carl
fat lime, thus showing that th
impart hydraulic properties to
been shown by Mr. H. St. Clai
of magnesium by itself is sometin
and sets under water. Other exp
indicate that magnesia might ac
place that element in forming ar
silica and lime. These results
to the hydraulic properties of th
independent of any action of
lime.

The silicates and aluminates
the property of hardening unde
salts of lime, and in some ceme
which would otherwise be requi
by magnesia. The action in
definitely known, and there is

by different investigators witl
true in a less degree with the l
times be rendered inert by too

Sulphuric Acid occurs in so
of lime, and sulphur also so
phide, usually of iron. Du
phide may become transfo
either or both forms may r
Experience seems to indicat
general, a deleterious subst
durability of mortar made fr
The sulphide, however, is su
draulic properties of the mat
doubtful. In Europe it is co
age of sulphur or sulphuric ac
the lime.

Phosphoric Acid occurs in
material of this character, a
action other than that of com
of lime, which is thus rendere

ART. 3. HYDRAU

The hydraulic activity of a
its ability to harden under w
upon the relative proportions
dients and of lime. Silica and
to be the effective hydraulic in
mon to designate the ratio of
of silica and alumina to that
its *hydraulic index*.

The hydraulic index gives,
limits, a measure of the hyd
classes of limes. It is to be
that there are other factors to
ing of the action of a lime tha
The other ingredients may by
draw portions of the active el
the effective ratio between them
lime depends largely upon th

limes according to the prop
tained by them.

When the hydraulic in
20/100 the lime is known
require from 12 to 20 days
draulic lime proper include
about 20/100 to 40/100.
or 10 days, the more rapid
as *eminently hydraulic.*

When the hydraulic ind
and 60/100 the lime is of
lime. These limes have
draulic lime, but form the
proper and the cements, l
and as a general thing not
of the hydraulic ingredie
cement. When burned a
give hydraulic lime of ra
properly treated and bur
makes good Portland cem

termine at exactly what point lime
but when it requires a month or
water it is usually considered as be

In determining the rate of ha
are so many external circumstan
the result that there is always c
causes classification by that me
uncertain. Variation in temper
important effect upon the rate of h

ART. 5. COMMON

Common lime is such as does
properties. It is divided into fat
lime, according to the quantity of
character it may contain. When
left in air it slowly hardens. T
ing consists in the gradual form
lime through the absorption of c
air, accompanied by the crystalli
hydrated lime as it gradually d
lime the final hardening takes pla
inward from the surface, as it is
tact of the mortar with the air.
pure the resulting carbonate is
soluble, and consequently to be
Nearly all limes, however, contai
silica and alumina, and these ing
quantities too small to render the

a certain power to set, causi
place with greater rapidity anc
ence upon contact with air. I
less soluble and more durable

Limes containing but a sr
consist mainly of calcium ox
and becomes hydrated very r
contact with water. This h
duces a rise in temperature a
which vary in amount accor
lime, the volume being doubled

The common method of sl
the quicklime with water, usi
volume of the lime. This m
ing. The lime is usually sp
haps 6 or 8 inches thick, in
poured over it and allowed
must be allowed for all of
When the lime contains much
tion frequently requires severa

Too great a quantity of w

Slaking by immersion is ac
By the first method, the lime
baskets for a brief period to p
the necessary water, after which
until the slaking takes place an

By the second method, spr
immersion proper, the lime b
sprinkled with the necessary
covered with sand and allowed

The difficulty in using thes
the right quantity of water to
plete. Lime so slaked may
in form of powder.

Spontaneous Slaking is also
it consists in exposing the lim
is effected by absorption of m

Lime slaked by immersion
slaked by drowning and req
into a paste. Slaked lime, ei
may be kept indefinitely if pr

Lime is commonly sold as
in lumps and not air-slaked.
been exposed to the air, it is
both moisture and carbonic
active, the portion combined
being inert. A simple test of
is to immerse a lump for a mi
and observe whether it swells,
with a rise of temperature.

Slaking some days in adva

order to insure the complete r
it is quite common to slake lin
is to be used.

The swelling of lime has be
by slaking with steam instea
has been found by Candlot
the addition to the water of
6%) of chloride of calcium
nesium.

Common lime is ordinarily
a mortar, mixed with sand.
the mortar should be just suf
the sand, without leaving any
lime. Mortar of rich lime sh
masses composed entirely of
likely to remain soft, so that
an element of weakness. If
the mortar may be porous
tions ordinarily required are
parts sand, and 1 part lime to

Mortar of common lime sh

often greater than that of cohesic
of mortar.

Meagre limes are similar in a
less energetic. They swell feeb
slight change in temperature. T
that of fat lime, but cracks less and
limes proper, those containing s
to materially reduce the energy,
ployed in construction.

Art 6. Hydraul

Hydraulic lime is obtained by
taining silica and alumina in suffi
the ability to harden under wat
ments are present in such quant
with a portion of the lime, form
nates of lime, leaving the remai
uncombined state.

the case of the limiting limes.
ally those which can be burned
complete the chemical combinat

It is necessary that sufficien
cause the lime to slake properl
that the quantity of uncombine
sible, as the setting properties a
aluminates, while the hydrated
the initial hardening of the mor

According to Professor Le
hydraulic lime should contain
aluminates are hydrated durin
and become inert, while the si
heat of the slaking preventing t

The following is given as a
best French hydraulic lime:

Silica. . . . .
Alumina. . . . .
Oxide of iron. . . . .

Hydraulic lime is used in the
lime, being mixed with sand to
air hydraulic lime acts like comm
and slowly absorbs carbonic ac
cracks when without sand, but m
In water, or in damp situations,
are altogether different. The hy
dens more or less rapidly. In
amount of the lime is at first diss
arrested as the hardening progress

Hydraulic lime is commonly sla
and shipped in form of powder.
out injury, in this form by coveri
the air.

ART. 7. MANUFACTURE OF

The manufacture of hydraul
carried on in Europe consists,

When full it is lighted at the bot
settles, new layers of material a
while the burned lime is drawn o
furnace being kept in continuous o
of burning is controlled by dam
cover at the top.

In furnaces of the second clas
of combustion are passed throug
not in direct contact with the fuel.

The regulation of a furnace to s
of burning is a matter requiring s
demanding the close attention o
lime must be completely burned
The character of the limestone
of burning necessary. A lime o
may be burned at a much higher
high index. When the limeston
acter it will not burn evenly, but
will be vitrified before that of
burned. The burning is acceler
moist, and stone fresh from the
that which has been exposed unti
has been evaporated.

The chemical phenomena of t
approximately as follows: The
first driven off. The carbonate
posed. Then the clay is dehyd
and the combination of the silica
lime takes place. The tempera
these changes depend upon the

composition of the carbonate of l
at a temperature of 700° C. to 900°
ture required for burning depends
silica and alumina present. Whe
is low the temperature must be suffi
combinations of the lime with th
in order to impart hydraulic prop
while if the hydraulic index be hi
little greater than that necessary t
may be sufficient, and a higher
would effect complete combinations
silica and alumina, may so greatl
of free lime as to destroy the proper

The *slaking* of hydraulic lime
plished by sprinkling, as mentio
lime after coming from the furna
4 to 8 inches deep in the slaking-
sprinkled so that all of the quickli
from 7% to 10% of water is comm

of silicate which is hydrated be
be imperfectly slaked, the free
may cause injury to the mortar
so affected will set more quickl
but afterward is likely to swell

Steam is sometimes used for
and is said by Le Chatelier t
the lime while producing no eff

It is claimed that the alumin
the slaking of the lime, being
steam, and hence are undesirab

After the lime has been red
ing it is forced through sieves
of all pulverized particles, but
size, including the underburn
burned parts which refuse to s
from the first bolting is known

ART. 8. GR

in silica and alumina, obtained fr
disseminated through the limesto
combination of the cinders of com
This is what is properly meant by

Bonnami found in his investiga
part of the grappiers are from the
stone which are in contact with t
the burning, and due to the silica a
ders. These cinders are usually qu

The grappiers are ground and si
to the lime or used separately as ce

The addition of ground grappi
has the effect of raising the hydra
and increasing its activity, and of
trolling to a certain extent the p
In this case the mixture between t
piers must be very intimate in ord
geneous material. It is also ver
lime in the grappiers be entirely s

It is employed with cement in n
etc.

ANALYSES OF LIME AND GRA

	Slaked Lime.	Me ab
	Per Cent.	Pe
Silica.	23.05	2
Alumina and iron oxide.	2.75	
Lime.	65.75	6
Magnesia.	1.50	
Water, etc.	6.95	

Art. 9. Pu

The term puzzolana is comm
materials which, when made int
or feebly hydraulic lime, impa
properties and cause the mortar
Puzzolana (or pozzuolana)
volcanic origin, deriving its na
of Italy near the foot of Mo

with clay in considerable proportion
the total volume. It may be ma
water, which will harden on dryi
times used for common mortar with

Psammites is a sandstone consisti
schist, feldspar, and mica, aggluti
cement. It is slaty in character an
a paste with water.

Puzzolana may be made artifici
and natural ones may frequently l
ing, which has the effect of dehy
alumina of which they are mainly
it in condition to combine readily

Berthier gives the following ana
ples of puzzolanas:

	Trass.
Silica.	0.57
Alumina.	0.12
Lime.	0.02
Magnesia.	0.01
Iron oxide.	0.05
Potash.	0.07
Soda.	0.01
Water, etc.	0.44

CH

CLASSIFICATION AND

ART. 10. CLA

HYDRAULIC cements
the method of manuf
ings: Portland cement
mixed cements, and gra
The term *Portland* (
nate hydraulic cement
of vitrifaction a mixtur
proportions and reduci
by grinding. The cem
draulic index than th

tain a minimum of 1.7 parts of lim
substances. The addition of 2%
matter may be tolerated in the m
cement, with the view of augmen
qualities, without the necessity of

Natural Cements are those wh
ing limestones less rich in lim
hydraulic limes or Portland ceme
like the hydraulic limes withou
raw material, and require a m
in burning than does Portland cen

This class includes a number
widely in composition and value.
commonly divided into quick-set
frequently called *Roman Cement,*
cements, known sometimes as na
In the United States there is m
the materials coming within this
confusion in their nomenclature.
monly designated by a name deriv
which they are obtained, and this
and satisfactory method. Thus,
those from the region of the
cements are from Southeastern F
cements from the Ohio valley, Po
cements from the corresponding
Akron, and Milwaukee are nam
tion of manufactories of particula

---

* Mémoires de la Société des Ingénieu

The term *American Ceme*
applied to include all natural ce
States. This, however, often l
of the fact that other than
made quite extensively in thi
American Portland Cement is a

The term *Rosendale Cement*
a general meaning and used as
and American to include all
however, more properly restric
district in which it was first ap
be no good reason for extendin
totally different material.

Slag Cement, or, as a more
Cement, is the product obtain
ture of slaked lime with fine
material, commonly blast-furna
the hydraulic ingredients are n
but are present in the cement
only.

ART. 11. MANUFACTURE

The manufacture of hydraulic
practised consists of four operatio
tion of the raw material, the burnin
grinding.

The methods of preparing th
according to the nature of the ma
to be used in burning. For natura
only necessary to select the prope
and break it into fragments of suit
tion into the furnace. The produ
requires the use of homogeneous m
be used to prevent the introduc
into a single burning.

The methods of preparing the
manufacture of Portland cement d
acter of the materials and the me

manufacture of slag cement (so c
materials are not burned together.

These materials are first to be
divided state and incorporated into
This is accomplished either by the
the details of the method varying in

In general where the dry method i
essary to pass the material through
to the grinders, although there are
which this is not done. These dryers
about 5 feet in diameter and 40 fee
nearly horizontal, the material pr
small fragments being fed into the upp
out at the lower end. The materia
proper proportions and ground to
powder, when it is ready to go to
kiln is to be used or to be made into
kiln is to be employed. In some
method is modified by grinding the
and afterward putting them through

great care must be exercised in secu
portioning of the ingredients and t
poration into the mixture. Careful
quently be made and proportions
proper composition to the cement
grinding is usually necessary in ord
may be very intimate.

Natural cement is commonly bu
vertical kilns in which the fuel and
together or in alternate layers at the
is drawn out at the bottom as the bu

For Portland cement rotary kilns
used in the United States. These
come into use during the past few
decreased labor cost of handling the
not so economical of fuel as some of
of kiln. These kilns are usually
and set with axis at an angle of abo
zontal. They vary from about 60 t

of lime-kiln, and is used by cha
charge of the cement material in
fuel in layers. It is then fired, an
plete, allowed to cool, after which

The continuous kilns in use ar
the *ring or Hoffman kiln* and the

The Hoffman continuous kiln
arranged in a circle around a cen
being fired at a time and the
passing through the chambers co
terial, the firing progressing from
continuously around the kiln.

The Aalborg kiln is a shaft kil
chamber is placed at the top, i
is fed in the form of bricks and t
ucts of combustion pass; below,
furnace in which the burning is
the fuel is fed, and at the botto
from which the clinker is withdra

The Dietzsch kiln is similar to

incomplete; a part of the lime r
lime uncombined with the clay.
light weight. In the burning, as
materials and the decomposition
lime is first effected, the limeston
out loss of volume, and thus suff
density. As the subsequent combi
the clay occurs, a contraction in v
the density becomes greater.

In stationary kilns the clinker is
chambers of the kiln and must
From rotary kilns the clinker dro
ture and must be cooled before p
For this purpose two principal m
In the vertical tower cooler the clin
with water is elevated to the top of
to slide down through the tower
upon which it is exposed to a c
rotary cooler the hot clinker pa

controlling the rate of setting and
of the presence of small proportions

After grinding, the cement is expo
purpose of allowing any free lime
to become air-slaked, after which it
bins or is put in barrels or sacks fo
instances keeping it for a time in
upon for aeration, while in others
altogether.

The manufacture of Portland c
care in the proportioning of the m
its subsequent manipulation. Eac
studied in order to determine the
give the mixture and the proper
secure the best results, and these op
closely controlled by frequent labo
grade cement is to be made.

ART. 12. PORTLAND

"This term is applied to the fine
resulting from the calcination to i
intimate mixture of properly prop
and calcareous materials, and to
greater than 3% has been made s
tion."

The Association of German Por
facturers in 1903 adopted the follo

"Portland cement is a hydrauli
with a specific gravity of not less tha
condition, and containing not les
weight of lime to each one part of
oxide, the material being prepared
ing the raw ingredients, calcining th
clinkering temperature and then
fineness."

These definitions imply that Po
artificial mixture of materials to se
tion. All Portland cements made
are of this character, but in France

the formation of active material.
of clay beyond this point, it form
surplus of lime remains in the ce
constitutes one of the chief danger
as, although it may not prevent th
cement when used, it may cause tl
swell and become cracked and disto

As perfect homogeneity is not
it is always necessary that the
excess in order that free lime
amount of excess of clay necess
upon the thoroughness of the pr
facture and the evenness which n
mixture of raw materials.

The hydraulic index of Portlan
about 42/100 to 60/100. The v
affected by the relative proportio
and iron oxide contained by the c
lent weights of these oxides diffe

while Table II, collected from v
analyses of a few of the leading
Portland cements.

TABLE I.

COMPOSITION OF PORTLAN

	Silica.	Alumina.	Oxide of Iron.	Lime.
French cements	22.20	6.72	2.28	67.31
	23.50	7.75	2.95	64.07
	21.70	7.48	2.57	65.54
	23.40	7.36	2.84	63.70
	24.50	7.09	2.81	62.40
	25.40	6.65	2.75	61.60
	21.80	6.56	2.64	57.42
	24.25	5.20	2.30	63.61
	22.30	8.04	3.71	58.68
	23.25	7.44	2.10	62.55
	23.00	8.33	3.87	60.90
	24.60	7.98	2.51	59.10
	23.15	7.83	3.37	61.40
	23.30	7.65	3.10	62.20
	23.15	7.88	3.37	61.30
	23.70	7.80	3.40	59.36
	22.25	8.22	3.38	60.48
	21.05	7.90	3.01	59.98

A large number of analyses c
cements are given by Professor T
for the most part about the same
those already given.

TABLE II.

COMPOSITION OF AMERICAN PO

	Silica.	Alumina.	Oxide of Iron.	Lime.
Sandusky.....	22.33	5.53	3.28	64.4
"	22.06	4.80	1.66	65.4
Atlas.........	21.30	7.65	2.85	60.9
"	21.96	8.29	2.67	60.5
Buckeye......	21.30	6.95	2.00	62.3
"	20.75	13.50		62.2
Giant........	23.36	8.07	4.83	58.9
"	19.92	9.83	2.63	60.3
Lehigh.......	22.96	6.78	2.54	63.9
"	22.13	9.56		62.6
Empire.......	22.04	6.45	3.41	60.9
"	20.80	7.39	2.61	64.0
Alpha........	20.38	....	....	63.3
"	22.62	8.76	2.66	61.4

principal ingredients. Heconclud
silicate, SiO_5Ca_3, is the only silic
drualic and that it is the essentia
ment. In Portland cement he finds
component, occurring in cubical
by combination of silica and lime
compounds formed by the alumina

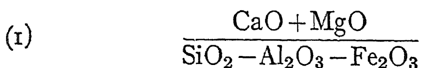
"The dicalcic silicate, SiO_4Ca_2,
property of spontaneously pulverizi
cooling. This silicate does not p
erties and will not harden under w
attacked by carbonic acid, formin
and thus contributes something t
of mortar employed in air. Th
nesia to form the double silicate
SiO_4MgCa, prevents the pulveriza
of no value for cement.

"At a very high heat the trica
posed into the dicalcic silicate and
ing inert."

function is to assist the combination
lime.

"This silico-aluminate, which is c
land cement on account of slow cooli
condition when the cooling is suffici
the case of blast-furnace slag pre
water. It combines with hydrate of l
gives rise to the hydrated silicates and
identical with those formed during t
land cement. It is these propertie
based the manufacture of slag cement.

Prof. Le Chatelier gives two limits
quantity of lime in Portland cement
found. These are, that the proport
always be greater than that represen



$$(1) \quad \frac{CaO + MgO}{SiO_2 - Al_2O_3 - Fe_2O_3}$$

and that it should never exceed that

aluminate being formed. If less lim
the bicalcic silicate would be forme

Formula (2) represents the point
of lime would be sufficient to forn
and aluminate to the exclusion of
If more lime than this be present,
form of free lime.

It is also stated by Prof. Le Ch
land cement of good quality form
3.5 to 4, and formula (2) gives 2.5 t

Dr. Erdmenger considers * that
borne out by experience, as they in
that magnesia may be considered
pointed out that the formation of
depends upon the temperature of l
ing to Prof. Le Chatelier, the tric
decomposed and become inert at
ture.

Dr. Erdmenger also states that
cooling may in some instances be
suddenly, as by plunging into cold
so treated the material does not becc

The examination of a considerabl
of good Portland cement shows tha
these formulas are commonly met
the maximum in formula (2) is
closely (from about 2.5 to 2.8)
formula (1) is, however, not usually

* Journal Society of Chemical In

cements, which give results var
4.5.

Newberry's Investigations.—M
Newberry have made a careful i
stitution of Portland cement f
forming, in the laboratory, co
alumina with lime and studyi
the effect of varying proportions.

Silicates of lime were formed c
and quartz ground to impalpabl
an intense white heat. The dic
as in Le Chatelier's experimen
cooling, but when suddenly co
water this was prevented and th
being ground gave a white pow
with water, set slowly and bec
day, and was quite sound. Th
gave a white clinker, sinterec
The powder obtained by grindi
slowly in water, becoming fair

with water and set in a few seco
after six weeks.

The aluminate, $Al_2O_3,2\frac{1}{2}CaO$,
heated strongly with water and s
distorted and cracked after three
cracked at six weeks.

The tricalcic aluminate, Al_2O_3.
in water and set quickly, but becan
in a short time, and disintegrate
in water.

The conclusions reached by
follows:

(1) Lime may be combined wi
of three molecules to one and still
tically constant volume and good
though hardening very slowly.
lime to one of silica the product i
in water.

(2) Lime may be combined wi
portion of two molecules to one,
sets quickly but shows good hard
$2\frac{1}{2}$ molecules of lime to one of
unsound.

"Assuming that the tricalcic si
aluminate are the most basic
exist in good cement we arrive at



in which X and Y are variabl

upon relative proportions of silica an
employed.

"$3CaO,SiO_2$ corresponds to 2.8 pa
to 1 of silica, while $2CaO,Al_2O_3$ co
of lime to one of alumina.

$$\therefore \% \text{ lime} = \% \text{ silica} \times 2.8 + \%$$

This formula represents the max
lime allowable.

Le Chatelier's maximum formula
form, leaving out of account Fe_2O_3

$$\% \text{ lime} = \% \text{ silica} \times 2.8 + \%$$

being based upon the tricalcic ins
aluminate.

Newberry differs from Le Chateli
the percentages of Fe_2O_3 and MgO
considered in determining the prop

what affected by the additional
fuel with which it is burned.
lower the per cent of lime in th

According to M. Bonnami a
formed, as with hydraulic lime,
duced less basic than the rest o
character of puzzolana. This
through the cement in grindin
raise the hydraulic index. It is
act like a puzzolana in combinin
hardening of the cement.

Richardson's Investigations.—
lier and the Newberrys have be
tending knowledge of the compos
land cement. Mr. Clifford R
further investigation into the
which is of much importance
understanding of the subject.

Mr. Richardson made micr

trial clinker. They are in fact o
aluminates in silicates of indefinite

Törnebohm had made a micros
land-cement clinker and found four
stituents, named and described as

"*Alit* is the preponderating elen
colorless crystals of rather strong
of weak double refraction.

"*Belit* is recognized by its dirty
muddy color and by its brilliant i
is biaxial and of high index of
small round grains of no recogn
acter.

"*Celit* is recognized by its deep c
It fills the interstices between tl
being the magma or liquid of low
of which the alit is separated.
refractive, that is to say, gives
examined between crossed nicol pri

"*Felit* is colorless. Its index c

two principal constituents of Portlar
and celit, as described above. Alit he
solid solution of tricalcic aluminate i
and celit a solution of dicalcic alumir
cate. These solutions may be of
concentration according to the relat
silicates and aluminates present up to
tion. These were studied syntheticá
being independently produced, and th
tion as in Portland cement by comb
silicate, SiO_23CaO, with varying pro
aluminate, $Al_2O_3.2CaO$. The limits
found by Mr. Richardson for cemer
calcic silicate with no aluminate pres
ratio of 7 tricalcic silicate to 3 c
$7(SiO_23CaO)3(Al_2O_32CaO)$.

Mr. Richardson's explanation of
these solutions is as follows:

"Having determined that alit and c
tions of aluminates in silicates, the alu

periments of Robert-Austen ha
mobility in solids exists, since
surfaces of gold and lead are l
left under pressure for some 1
temperatures, gold is diffused
lead into the gold for an ap
tures of the components whicl
ble wood metal when subjected
temperature become converted
drous sulphate of soda and c
diffuse when brought into close
tion of barium sulphate and c
not difficult to understand, ther
ture of 1650° C. the particles
lime may diffuse below the mel
clinker to form a Portland cem
a clinker is stable depends no
but upon the fact that the diff
even in material which is only s
fore, may be defined as diffusio

perature is a function of the tem
longer the lower the temperature.'

The work of these investigato
our knowledge of the constitutio
various cement materials and ma
proper composition for Portland
limits.

Further investigation is, howe
definite knowledge of the actions
cement and of the rôle of the ing
three principal ones. The part pl
in doubt, while iron oxide is supp
similar to alumina in forming c
"Iron oxide combines with lime
like alumina in promoting the co
lime. For practical purposes, ho
iron oxide in a clay need not be c
the proportion of lime required.

This is based upon the suppos
is insignificant in amount

would be needed for Portland c
vary greatly in composition and
of such composition as to ma
increasing the content of lime,
amounts of alumina or of magn
missible in materials for Portlan

The quick-setting natural cen
ents as they are called in Europe,
at a low temperature, argillaceo
high index. These cements are
a very rapid set and slowness in
quently. The feeble burning giv
and the formation of the silicates
as in the heavily burned Portlan
able percentage of aluminate of
is the cause of the quick set. S
is also commonly present in such
inert matter. Material of this
when the temperature of burni
point where the chemical reactio

mixtures used in making Portland
tion of lime cannot be so great as in

TABLE III.

COMPOSITION OF EUROPEAN

	Silicious Sand.	Silica.	Alumina.	Iron Oxide.	Lime.
1	....	22.60	8.90	5.30	52.69
2	6.00	24.80	7.00	4.80	44.12
3	....	21.70	8.29	3.71	52.68
4	....	23.60	7.99	4.31	57.40
5	....	21.80	10.03	3.77	55.60
6	2.00	26.80	10.39	4.61	46.10
7	10.70	30.80	7.82	5.13	33.04
8	2.40	25.45	9.25	3.85	47.95
9	....	29.55	8.35	4.10	47.50
10	....	21.00	8.40	5.10	52.05
11	....	23.40	12.90	3.30	47.70
12	0.85	29.05	7.95	3.75	46.05
13	....	25.85	9.10	4.10	51.60
14	4.35	27.35	7.73	3.85	50.25
15	....	25.85	10.00	4.85	54.20
16	....	29.10	12.50	4.65	48.60

of this character, therefore, requi
to produce good results. As th
comes greater the homogeneity b
as free lime becomes less likely to
ous, and irregularities only have
the quantity of inert matter, whi
from the cement to gain streng
than with Portland cement of lo
observed that the material spoken
delays the gain in strength in the
ing, may not be altogether iner
to the final strength of the cement,
character and perhaps ultimatel
hydrated lime in the mortar.

These cements occupy an int
tween the artificial Portland cem
cements, and may approach eith
fact, the same raw material ma
either—if burned lightly, giving th

properties is well known, their acti
Fremy being probably much slower
ing lime-salts.

The action of cements of this clas
lar to that of Roman cements: the
slowly, but may be either quick-
composition of the magnesian ceme
of the Roman cements to one in wh
magnesia is as large as that of lime
of magnesia to lime increases, th
considering magnesia as lime, frequ
becomes less than would be adr
cement.

Magnesian cements are but little
in the United States they form th
natural cements in use, and many of t
by experience to be very useful ar
Table IV gives analyses of Ameri
from various districts, showing somet

TABLE IV

COMPOSITION OF AMERICAN

District.	SiO_2.	Al_2O_3.	Fe_2O_3.
Utica........	27.60	10.60	0.80
“	34.66	5.10	1.00
Louisville......	26.40	6.28	1.00
“	22.54	8.28	2.14
“	23.29	5.96	2.16
Potomac......	28.02	10.20	8.80
“	30.22	8.38	5.38
Hudson.......	27.98	7.28	1.70
“	28.91	10.96	4.68
“	31.28	11.30	
“	27.30	7.14	1.80
“	30.78	8.68	
Akron.........	22.62	7.44	1.40
“	26.69	7.21	1.30
“	20.75	10.02	
Milwaukee.....	23.16	6.33	1.71
“	25.00	4.00	2.80

The rock from which these ce
greatly in character in the sam
different strata of the same qu

ally materially changed by age
are kept exposed to the air fo
of time, they gradually become
haps eventually lose the powe
sometimes becoming puzzolana,
active cement by reburning.

Art. 14. Slag

Slag-cement is formed by the
with ground blast-furnace slag.
mately the composition of a hyd
a proper proportion of lime to ren
These cements are sometimes ca
the slag used being of the same
commonly employed in making li

The method employed in formi
the slag suddenly by plunging i
as it emerges from the furnace
granular, and causes it to retai

this ratio. He also finds that the b
from slags giving a ratio

$$\frac{Al_2O_3}{SiO_2} = 45/100 \text{ to } 5$$

M. Prost * states that a consid
phur may be unobjectionable in s
tions a case where good results h
sulphurous slag, the only effect bei
uted to sulphide of iron. He als
is most advantageous for this p
rich in lime and alumina.

Slags in actual use for the man
vary considerably in compositi
ranges from about 1.30 to 1.80,
from 0.40 to 0.90. In most instan
together, that is, the high-lime ra
material as the high-alumina rati

stitute quicklime for slaked l
for slaking, but unsuccessfully
some extent with the lime and th
while particles of quicklime b
cause swelling of the mortar aft

In some of the European
ground and bolted through f
mixed with the lime, but more
slake and bolt the lime and th
slag before grinding, or to do t
in two stages and make the n
and second grinders.

The lime may advantageousl
after slaking before being used,
plete reduction of the quicklim
deteriorate when kept long aft
commonly employed for this p
to be an advantage in using m
the mortar being less likely to cr
M. Prost found that there was n

The composition of slag cem
that of Portland in having a les
silica and alumina, and more a
the silica.

Table V gives the composition
of the leading European slag cem
and Tetmajer.

TABLE V

COMPOSITION OF SL

	Silica.	Alumina.	Iron Oxide.	Lime.
1	24.80	19.13	2.67	36.60
2	24.60	13.46	0.84	50.22
3	24.90	13.46	2.83	50.40
4	24.30	13.85	1.15	49.50
5	27.45	14.65	1.75	46.20
6	25.20	15.23	0.77	50.00
7	20.40	18.59	0.41	50.07
8	18.30	18.07	0.34	53.16
9	22.35	12.83	0.64	55.61
10	27.35	9.13	1.50	50.28
11	20.35	14.05	0.33	50.26
12	18.69	9.20	2.14	46.36
13	19.87	14.84	0.80	48.54

Mr. Redgrave also says that it
time without injury, and if kept
that it undergoes no change what
nami states that exposed to air
loses its hydraulic properties, p
bonization.

ART. 15. MIXED C

The term *Mixed Cement* is sc
clude a considerable number of
formed by a mixture of various
works where other cement is m
may be made either for the purp
product or of imparting to it cer
They consist of admixtures of diffe
of the overburned or underburne
or of foreign material added to t

Slag cements and certain nat
like some of the Rosendales, are r

being mixed with natural cem
Portland cement being addec
strength and reduce the rapid
Cement of this kind is usua
nation of Portland or natural
ing to its real character. Som
and regularly made give good

ART. 16. GRAPPI

Grappiers cements are mad
the grappiers left from the slakin
lime. Very great care is neces
the free lime from the grappi
the operation of slaking and bol
times. The grappiers includes
and overburned material forr
fuel, as well as a certain amoun

being present to slake the partic
which it is air-slaked before pack

ART. 17. SAND C

Sand cement is the name give
by grinding together Portland ce
extremely fine powder and a v
It is claimed that a very conside
may thus be mixed with the cem
reducing its strength, and that the
may still be mixed with the usual
sand and give good results in use.

It is said that the additional grin
in pulverizing the sand reduces the
powder, thus increasing its pow
Experiments also seem to indicate t
separately, a certain amount may
without serious injury to mortar n

CHAPTER

THE SETTING AND HARDE

ART. 18. THE SETTIN

WHEN cement powder is mixed
condition and allowed to stand, it
a solid mass, taking the water
soon becomes firm and hard. T
tion amongst the particles of th
the *setting* of the cement.

Cements of different characte
their rate and manner of setti
a few minutes in the operation
several hours. Some begin setti

rupture before any perceptib
place.

It is sometimes stated that
volved in setting is an instanta
the time we call the beginning
hardening then begins and is
the maximum strength is reach
with some cements a quite n
shows itself at about this tim
water from the surface of th
stiffening of the mass.

ART. 19. THE HARDENIN

After the completion of the
mortar continues to increase
a considerable period of time,
velopment of strength is ea
cement

strength rapidly and attain
few days, while others hard
continue to gain in strength
of early hardening gives bu
mate action of the cement,
mortar may be the same h
is attained.

Portland cement usually
gains its maximum strengt
cement, and also, as a rule,
greater final strength whe
Of two cements of the sa
safe to infer that that whic
will prove the stronger an
in fact, where an abnormal
a few days the presumption
the cement giving such resu
ing at a more moderate rate

The rate at which ceme
use depends, of course, up

THE SETTING AND HARDE

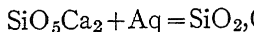
ART. 20. CHEMICA

Very little is definitely known
ical reactions which take place i
and hardening of cement mortar
been proposed to account for the
observers, based mainly upon the
of various compounds of lime, sil
synthetically. Chemical analysis
of the various elementary substan
is composed, but not their state
action of a cement may be grea
the condition in which the ing
changing the manipulation in ma
ing their relative quantities.

Fremy considered Portland c
plex in composition, and ascribed
of lime upon certain puzzolanic
of double silicates of lime and al

while soluble in an anhydr
when hydrated. When the
in mixing mortar the anhy
then, becoming hydrated, t
the saturated solution in a
which are thus capable of
drous state and then becom
in two ways—by decompos

The tricalcic silicate, w
of Portland cement, is dec
to a hydrated monocalcic



The monocalcic silicate
needle-like crystals and th
visible to the eye. The t
by simple combination wit



The first setting of Portlar
the hydrating of the alumin
while the subsequent harden
progress of the hydration of
rapidity of set is therefore
tive proportions of alumina
the burning is done at a lo
the aluminates, which are first
set, while as the degree of
the aluminates give place to
setting to become slower an
strength greater. The alumi
but little to the final strength
not permanent compounds, bu
and various salts with which
contact in the work.

Cements of low hydraulic
and gain their full strength
index. They are more nearly
according to the theory shoul

they lose strength after hardenin
probably due to the decompositio
the parts of too low hydraulic ind
This loss of strength is usually temp
is of normal composition; but if it
of strength may continue, to the f
mortar.

The experiments of M. Cand
presence of carbonic acid is esse
of hydraulic cement mortar. H
mortar were placed in distilled wa
it became gradually decomposed
coherence; but the presence of
common in all natural waters, pre
caused proper hardening to take p

Mr. Clifford Richardson offers
tion of the phenomena of setting a
land cement, assuming the ceme
solutions, as indicated by Richa

composed Portland cement together
istics of the silicates and aluminat
latter are acted upon much more ra
and it is to the crystallization of th
nates that the first or initial se
Subsequent hardening is due to t
lime from the silicates. If the l
rapidly than it is possible for it
the water, expansion ensues and
volume constant.

"The set of Portland cement is
the decomposition of the alit alo
thin section of a neat Portland-ce
that it contains large quantities o
a certain amount of unattacked
ends of a neat Portland-cement bri
by means of a rubber band and
time in water the pieces of the b
to have become cemented togethe

the greater its strength is known
burned."

As already pointed out, ceme
alit) gain strength more rapidly
(much celit), but it has freque
cements slow to gain strength
or stronger than those which
This would seem to indicate
low in lime (celit) may play a
the ultimate hardening of ceme
monly supposed.

ART. 21. INFLUENCE OF

The action of sulphate of lin
setting of Portland cement is
many it has been common to
of regulating the rate of set, by
to the cement.

Candlot * has made a care

exposure soon becomes quick-sett
exposure again becomes slow.
with the sulphate of lime has re
by exposure, it may again be ma
of a small quantity of lime. Fres
of lime added, and setting slowly
rapidly if the mortar be mixed wi
bonate of soda.

"Cement having sulphate of
rapidly when mixed with sea-
water, and that which has been
its former activity sets more ra
than when mixed stiff.

"The addition of a small quan
to Portland cement augments th
mortar is kept in sea-water and th
exceeds 1 or 2 per cent, the mor
disintegrates. When the cement
was kept in sacks during severa
strength during the early period

and fails to prevent the imm
nate.

Aluminous cements burne
contain considerable alumin
bear an addition of 5 to 1c
out loss of strength. The
always be limited to what
aluminates.

ART. 22. INFLUENCE

Candlot has also made a
upon the setting and hard
chloride of calcium, either
which the cement is mixed
is immersed. He found th
with water containing a few
of calcium sets more slowl
water; while if the solution
100 to 400 grammes per lit

same solution it will not set or h
treated in the same way hardens
a hardness comparable to that
"Feeble solutions of chloride
preciable effect upon cements
like certain grappiers cements
sively of silicate of lime.
"From this the conclusions a
"1. That in Portland cemen
feeble proportions; that it acts
upon the set, but very little u
is caused by the silicate of lime
"2. That in the Vassy ceme
is the essential element, and de
and the hardening; the rôle o
portant, especially during the e
"3. That in the phenomen
quantities of the elements pres
The solution of chloride in pre
of the aluminate of lime perh

with a solution of 100 to 400 grar
very quickly. This set is accor
in temperature. This only occ
With an old cement the setting
temperature is produced, and th
integrates.

"Mortar of cement gauged w
tion of CaCl is disintegrated i
diately after setting, but 15 or 2
perhaps be submerged without l

"The action of a concentra
Portland cement is due to the fa
is attacked very energetically
it is very slightly soluble in a
solved in large quantities in a c

"When a fresh cement is agit
solution of CaCl it dissolves no
the oxide of lime. The lighter
more it will dissolve. When a
with the concentrated solution

characters, however, vary consi
to "take sand" without loss of
weaker ones may not be able to t
weight of standard sand, whil
with considerably more than th
loss of strength at the end of
All have a certain limit within w
stronger by an admixture of go
be if mixed neat.

Cement mixed with sand alwa
than neat cement, and requires
attain its maximum strength. A
to cement is increased, both the
final strength are diminished.
however, the strength of mortar
period of time as the proportion
and as the time of observation
strength due to larger proportio
Thus a good Portland cement
1 part sand to 1 of cement at th

in mortar than that containing
earth, or that composed of r
sand also usually gives greater
is very fine. It is often diffic
the quality of sand without ex
some cases a small amount of
to injure the strength of the
mixture in the sand of grains c
benefit through reducing the vo

A mortar composed of sand
sesses greater ability to adher
coarse sand is used than if the

ART. 24. WATER US

The quantity of water used
one of the most important cond
tity, provided there be sufficie
the mass of cement, the quick
some Portland cements, chang

to reduce the mass to a plastic
not be so thoroughly compact
same strength as when made
applied to it. But if just su
thoroughly dampen the mor
plied to expel the air and c
strength will be greater than
This difference, like the for
certain extent with time, but t
greater with the less quantity o

According to Prof. Le Cha
crystalline mass varies with t
mode of aggregation of the
strength of a single crystal
ence to neighboring crystals.
give greatest strength, and cr
more as the solution is more st

The nature of the water
affect the rate of setting. W

Mortar kept immersed i
more rapidly than that kept
ence is commonly much mor
than with mortar contain
of sand. The strength ga
although gained much mor
final amount than that in fre
a very great difference bet
particular.

Cements with a low hydr
difference between sea an
taining small quantities of
early strength in sea than
sooner disintegrated by the

ART. 25. EFFECT

Cement mortar kept und
more rapidly in the early
the air, but usually that k

The nature of the water in whi
to harden is of more importance
of the water used in gauging.
be kept in air, the nature of th
becomes more important, althou
tions in ordinary natural water
produce any appreciable differen
mortar. Mortars gauged with s
air.

ART. 26. EFFECT OF T

The temperature of the water
important bearing upon the tim
the higher the temperature, wi
more rapid the set. Many c
several hours to set when mixec
perature of 40° Fahr. will set i
temperature of the water be i

evaporation of the water from th
may cause drying cracks in the

Quick-setting cements usually
perature during setting, due to th
which takes place. It has been
occupied by the setting would b
serving the period of advanced
noting the stiffening of the morta
slow-setting cements, however,
change of temperature, if any ta
ciable; and the rise in temperat
place, may not always be the result

If the air at the time of mixin
cold to freeze the mortar before i
while frozen; but most cements
out, and but few of them will be
in so far as their ultimate strengtl
experiments * have, however, seen
may set while frozen if it remain
sufficient length of time.

The temperature of the air
mortar is immersed during the
a very appreciable effect upon
of many cements. This effect
different material; with some the
ated by keeping them hot as comp
the result in cold air or water; o
affected, while still others seem
hardening by the application of
to be found among cements of
seemingly independent of their
hydraulic index usually show t
of hardening under the action o

ART. 27. EFFECT OF AG

The effect upon a cement of
before using depends upon the
and the method of keeping. V
closed so as to prevent the acc

usually becomes slower-setting w
without injury as to its ability to
strength.

Light-burned cements, particu
are affected in much greater d
cements not only become slower
to the air, but commonly also
power of hardening and become
cases becoming puzzolanic materi
may be restored by the addition o

The changes which occur in c
are attributed to the action of c
free lime which they may contain,
the less stable compounds, as t
which contribute to the rapid se
plentifully in the light-burned mat

ART. 28. EFFECT OF

in a useless condition much o
active portion of the cement.

The rate of setting is acce
which the cement is grounc
finely ground cement the am
greater than in one coarsely
reactions which take place in
fine subdivision of the partic
gauged with sea-water the rate
by the fineness.

The hardening of cement
affected by fineness; that fine
more rapidly, but attains less
more coarsely ground. The
ground cements is more grad
ultimate strength greater.

Cement, when used, is con
and the attainment of streng
than mortar of neat cement i

with the fineness, at least in
ening.

The difference between coa
greater in the early period
The fine cement hardens muc
coarse cement, especially in ri
nearly the same ultimate stren
extreme fineness may not theref
when the extra cost is considere

CHAPTER

THE SOUNDNESS C

ART. 29. PERMANENC

THE permanence of any stru
of cement is dependent upon tl
after the setting and hardening
to retain its strength and form ı
nite period. Experiment has sl
from cement of good quality fre
in strength and hardness thro
years, or at least that there is
of strength with time; and that

in volume, together with an incre
transference the other way may
result; but no distortion of for
the mortar will take place in eit
be of good quality.

Sometimes cement when mad
hardens properly, and later, whe
of the atmosphere or water,
cracked, or even entirely disinte
sition deviates but slightly from
of disintegration may not show
time, and proceeds very slowly
element of considerable danger,
detection in testing the cement.

The unsoundness of cement m
by defective composition, causin
to the action of expansions proce
or by exterior agencies which a
the cement susceptible to their in
to act by the method of making

which gain strength very rapidly
quite apt to act in this manner, and
noted, the cement may not posse
resist, and the expansive action
disintegration.

The term *Permanence of Vol*
power of the material to resist
or dimension in the body of mo
synonymous with *soundness*, if by
its power to resist disintegration
Most unsound cements fail by
under the action of expansives.
ever, the failure occurs by a gradu
of mortar, without appreciable ch
sion, the process being very slow, s
for several months after the mort

Art. 30. Free

burned at a low temperatur
that where the addition of c
the carbonate produced no r
nitrate caused swelling an
The presence of free lime
low index is therefore of spe
carefully guarded against by
tion and complete reactions i

The fineness of the cem
of the free lime, as finely
quicker than coarse grains,
to become hydrated before
the cement be exposed to
in a fine state will sooner b

If free lime be present in s
slaked before the initial set
injury. If it becomes slake
period of hardening, the str
reduced, being rendered les
In case this action be not su

These effects may afterward gradua
they probably have the effect of ma
more easily attacked by external ag
of low hydraulic index, which gain st
the early period of hardening, are
to contain appreciable quantities of fr
frequently shown by a loss of strengt
extended over a considerable period o

Mortar kept under water is acted
rapidly than that exposed to dry air.

ART. 31. MAGNESIA.

Free magnesia in cement acts ver
lime. The action of magnesia, howeve
than that of lime, and for this reason it
defect, because less likely to be dete
applied before using. Prof. Le Chate
cent of lime and of magnesia with two

limit the amount of magnesia
Portland cement.

When mortar fails from this c
may not be shown for several
has set, and then in a comparat
ing, cracking, and disintegration

Dr. Erdmenger made a larg
upon the effect of adding sma
to Portland cement, and found
water and contracted in air; t
able percentages disintegrated,
weeks.

The fineness of the grains o
lime, is important as affecting t
Prof. Le Chatelier found that
ground produced swelling and cr
of finely ground magnesia prod
out distorting or cracking the
the change in volume varies wi

in a work swelled and cracked, a
showed that it contained 16 to 28 pe
Experiments were made by mixing r
cement, and swelling resulted. The
for the manufacture of the cement
proportion of magnesia, which was
an uncombined state in the cement.
the swelling occurred was found to
amount of water available. When mi
quantity and left in dry air no expans
is therefore only dangerous in water.

Analyses of this cement are given as

Silicious Sand.	Silica. %	Alumina. %	Iron. %	Lime. %	Ma
....	14.80	8.00	4.60	47.30	2
....	18.30	2.95	3.60	44.80	2
0.35	20.70	3.35	3.65	43.30	2

This is not similar to the magne
monly used in the United States on

not been shown, however, th
in the setting of these salts,
contribute to the final stren
of the process, it is certain
cements continue to increas
period, the proportionate in
being much greater than fo
very moderate action.

ART. 32. ALUMI

The exact rôle of aluminat
a matter of considerable dou
the basic aluminates to act
like lime, being decomposed
action of water upon these al
being given off, with the re
the set of cements contai
quantities.

The disintegration of mort

with the aluminate may take pla
causing swelling and, if sufficient
tion of the mortar.

Aluminates should therefore b
to be used for mortar to be ex
sea-water, as the sulphate of m
lime of the cement, forming the
then combines with the alumina
the expansive action. For this
alumina are not considered desira

ART. 33. SULPHUR (

The action of sulphur in cem
able, depending upon the state
and the nature of the cement. T
phate of lime for the purpose o
slower has already been discu
action depends upon the presenc

that of adding it afterw
two seem to give analogo
burned cements it may be
and hence slow in acting u
the expansion to be delay

Mr. Spachman, who
duction of Portland cem
cludes * that the danger
too large proportions of s
likelihood of forming calc
burning, which afterward
the cement, the sulphide
posure is oxidized to a s
color of the cement to a
much of its activity, in s
at all. Mr. Spachman gi
SO_4Ca as what may be sa

Prof. Tetmajer states t
land cement sometimes a
the fact that it is readi

Art. 34. Exteri

The principal exterior ag
cause the destruction of mor
perature or in humidity and
with which it may be in cor
ical agencies, such as the shoc
sand produced by a current,
and may oxertax the strengtl
period of hardening, but they
tion through injury to the cem

The effect of frost is to se
through the freezing of water
tar and resistance to it proba
the strength of the mortar an
expansion.

The nature of the water to
posed is important because
action of salts which it may

which forms a deposit in the
on the contrary, the dissolving
which traverses the mortar is al
a large quantity of carbonate
is carried off by the water."

In regard to the effect of tem
says: "At elevated temperatu
lose their water and are reduce
talline carbonate of soda, an
of the mortar. This is the ca
of lime, especially the alum
experiments are still necessary

"This dehydration occurs i
the well-known fact that certa
in water and attain high stren
to dry hot air disintegrate int

M. Candlot says that "alu
ject to alteration in surrounc
dryness and humidity, and als
temperature." It should be

and perhaps ultimate destruction o
ent cements vary greatly in the ext
influenced by this cause, slow-setti
being ordinarily least and the slag c

ART. 35. EFFECT OF S

The destructive effect of sea-w
mortars which are sound in fres
due to the action of magnesium s
the cement, thus forming sulphate
cium. The action of these salts u
cement mortars has already been d

When mortar in sea-water fails b
is usually attributed either to to
of free lime or magnesia, or to
the cement. When the cement co
expansive action is greatly intens
compared with that in fresh wate
plained by the presence of calc

salts may be washed out, lea
to the action of the disintegrat
of any Portland cement may
sea-water if used in such ma
tinuous action of the magnesi

The ultimate hardening o
in fresh water, seems to depe
bonic acid in forming a prote
tion of the elements of disinte
resists the penetration of the
renewal in the interior of t
becomes protected by the a
and effectually prevents furth
salts.

M. Durand-Claye examine
wall where parts of it were
large proportion of magnesia
tained in the original mortar
wall which were still sound
phuric acid was also incre

fresh water were unaffect
disintegrated in six month
in fresh water suffered a s
acid, while those in sea-
loss of lime and gain in m

M. Alexandre also fou
calcareous sand is attac
containing them may be d
is good."

CHAPTE

METHODS OF TES

ART. 36. OBJE

TESTS of cement may hav
the examination of the qualit
to determine its fitness for u
properties of the cement for
knowledge of its behavior unde
of use. Where experiments
object, the tests to be applied
must of course be dependent
be investigated.

laws governing the action of
examinations upon particular p
take into account the variable
and the necessity for exact kn
the cement upon which the test

The French Commission up
ing the Materials of Construc
the permanent laboratories ce
atically tested in the followin
analyses; fineness; specific gr
homogeneity; time of setting;
ural, and adhesive strength;
porosity; permeability; resista
sea-water; and yield of mortar.

Tests of cement, as common
upon engineering work, have
determination of the quality of t
for the use. Tests for this purp
ing to some recognized stand
approximate the conditions o

cumstances of its use. The
material varying so greatly in ch
under various conditions is evi
lar brand of cement whose cha
may readily be determined whe
normal quality, and something
future from its behavior unde
little, however, can be done in
and for a new and unknown n
to state a somewhat indefinit
results.

Tests may be imposed whic
secure good material, but oft
jecting equally good or better
will be unavoidable until the cha
brands of cement are more full
which each should be subjecte

The tests which are usuall
the quality of hydraulic ceme

in so far as it has been shown b
subsequently maintaining such
to produce cement which will de
short-time tests is liable to result i
index, or the addition of calciu
times in the presence of free lime
likely to be unsound than one of

The test for soundness or pe
an important one, as giving an ir
durability of the material; but
tests, a knowledge of the usual ac
contribute greatly to the proper i

The test for fineness is also im
the power of the cement to take

It was recommended by the co
Society of Civil Engineers upo
testing, that tests for quality b
three most important tests—fi
and soundness; and this recomm
monly followed in the United S

and well burned. Variations
the weight, so that there may
in the weight of various cement
well burned.

The apparent density is af
which the cement is ground;
of the cement the greater its
The weight test when emplo
combined with one for fineness
of heavy weight by coarse gri

The test for apparent densit
for the reception of material, a
in result. It is, however, somet
tions in England, and is used i
tories where a careful study is
cement.

As the cement powder may
so as to give very different wei
it is necessary to use a unifo

measure (M) of I litre capacity ar
provided with ears which catch u
two levers (L). The frame is raise
turn of the hand-wheel by the cam
cession of jars to the measure.

Above the measure a sieve (R
system of levers which are hinged
by the rod (V), giving two oscill

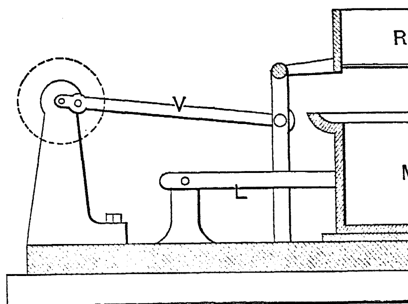
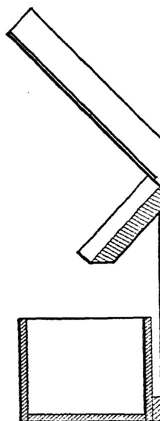


FIG. I.

Inclined-plane Apparatus
ratus for apparent density
of forms, one of which, em
mended by the Commissio
Matériaux de Construction,



Fi

The cement is poured in small q
mit of the secondary plane so slow
opening between the planes, until
when it is struck and weighed.

A single inclined plane of som
(50 cm.) is sometimes used, the
upon the upper end and allowed
the measure. It is said, however,
results than the double plane
extreme care.

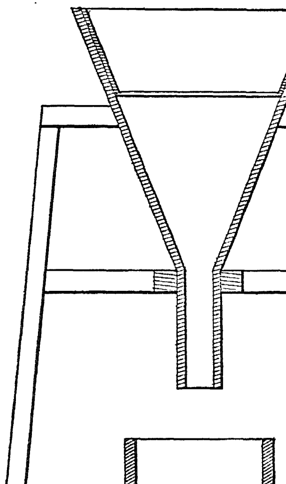
German Funnel Apparatus.—
recommended by the German con
of testing materials, as was also th

The funnel is formed of a holl
vertical, as shown in Fig. 3. Th
is 18 cm., its upper base is 20 cm.
in diameter, terminated at the lo
cone 5 cm. high, with a lower bas
The funnel is supported upon a

with a sieve fitting into th
measure below. The ceme
gradually worked through
then slides down the funne
is filled.



requires careful manipulation to se
rate of filling the measure and t
compacting. The inclined plane
funnel apparatus are found to give
recommended by the commission



creased weight which wou
grinding. The coarse parti
hardest burned and therefo
cement. To accomplish this
fine as possible in order to
pable powder. In Europe
square centimeter is employ
sponding to the No. 180 siev
inch.

The Committee upon Cem
Society of Civil Engineers,
method of making weight t
American engineers. This to
practical use and it is not cu
to make any test of this c
results of such tests under
great, and the results are so
of grinding that when a dens
gravity is usually determine
1904 recommended the speci

method of determination which c
tests. The differences of specific gr
are, however, very small, and grea
the manipulation of the test in or
results.

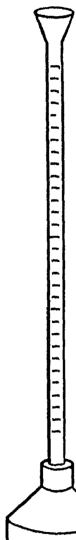
The test for specific gravity is
immersing a known weight of th
which will not act upon it, and
through noting the volume of
making the test by this method it
the air-bubbles contained in the
eliminated, and that the volume o
cement particles only.

Schumann Volumenometer.—Seve
have been used for this purpose. C
volumenometer, shown in Fig. 5,
common. It consists of a gradu
of which is ground to fit closely int

In the use of the apparatus the

through a long funnel, thus
of the tube dry.

In some instances greater
obtained by filling the appara

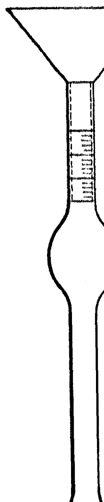


of the apparatus the tube is tu
and the bulb filled with benzin
placed upon the tube, the appara
reading taken of the height rea
A weighed quantity of cement i
tube, which is turned upside dow
the flask for the purpose. The fla
the whole again inverted, the volun
of the liquid in the tube. In orde
bubbles the apparatus is shaken b
reading so as to thoroughly mix the

This method is much more rap
Schumann volumenometer, but in
satisfactory in result.

Le Chatelier's Volumenometer.—T
in Fig. 6. It consists of a flask th
out into a tube 1 cm. in diameter an
the middle the tube enlarges into a
and then again continues with u
top. The flask to a point marked

weighing the apparatus before
introduced. Or, this volumer
the same manner as that of
serving to prevent the cement s
tube.



commonly somewhat volatile and
be kept low in order that the res
be affected by the evaporation
is used the temperature should no

The committee on Uniform T
American Society of Civil Engin
the use of the Le Chatelier appar
ratus be submerged in water in a

The recommendation of the co

"*Significance.*—The specific gr
ered by underburning, adulterati
the adulteration must be in co
affect the results appreciably.

"Inasmuch as the differences
usually very small, great care mu
ing the determination.

"When properly made, this tes
for underburning or adulteration.

"*Apparatus and Method.*—The
gravity is most conveniently ma

the lower mark and 64 grs. (2.25
viously dried at 100° C. (212° F.) ar
perature of this liquid, is graduall
the funnel (the stem of which ext
top of the bulb) until the upper m
difference in weight between the c
the original quantity (64 grs.) is t
displaced 20 cu. cm.

"(2) The whole quantity of the
and the level of the liquid rises to
graduated neck. This reading pl
volume displaced by 64 gr. of the

"The specific gravity is then obta

$$\text{Specific gravity} = \frac{\text{Weight}}{\text{Displa}}$$

"The flask, during the operati
in water in a jar, in order to a
temperature of the liquid. The
within 0.01.

land cement varies from about 3.
ally above 3.05. Natural cemen
3.10. An inferior limit is someti
tions—usually for Portland cement
for Roman cement about 2.80.
often specified for natural cements

The presence of the volatile e
plete burning, or of adulterations
ing, tends to lower the specific
of adulteration, however, needs to
it becomes appreciable in the resu
ical composition also to some ex
gravity, cements of low hydraulic
values. The age of the cement
aeration tends to reduce the spec
of fresh cement. The specific grav
density, is not affected by the fin

This test is not commonly a
for the reception of cement upo
work

that the cement will give goc
sand.

The fineness which should
matter of relative economy;
larger the quantity of sand
used with it. The coarse pa
be considered as inert material
amount of sand already mi
is a question therefore of relati
of fineness.

There is, however, some d
fineness. Some European au
dom of a fineness test. It is
of fineness in the strength of
some extent with time, but th
to be the really valuable part
be omitted the cement loses

Prof. Le Chatelier in his
of mortar found that, after
particles no trace is left of

The Committee of the America
gineers in 1904 recommended wit
ness test as follows:

"*Significance.*—It is generally a
particles in cement are practicall
the extremely fine powder that
cementing qualities. The more fin
all other conditions being the sa
will carry and produce a mortar c

"The degree of final pulveriza
receives at the place of manufac
measuring the residue retained on
known as the No. 100 and No.
mended for this purpose.

"*Apparatus.*—The sieves shou
20 cm. (7.87 inches) in diamete
high, and provided with a pan, 5
and a cover.

"The wire cloth should be wo
brass wire having the following d

"*Method.*—The Committee,
has reached the conclusion t
not as practicable or efficient as
recommends the following meth

"The thoroughly dried and
is weighed and placed on the
pan and cover attached, is hel
inclined position, and moved
at the same time striking the
of the other hand, at the rat
minute. The operation is
than one tenth of 1 per cent
minute of continuous sieving.
then placed on the No. 100 sieve
The work may be expedited
small quantity of large sho
reported to the nearest tenth

The British Standard Spe
Engineering Standards Comm
following requirements for fin

ART. 40. NORMAL CONSIST

In order to secure uniform results in
as well as for rate of setting, it is essen
ard consistency be adopted for the
mortar. The effects upon setting ar
varying the quantity of water used in mi
been discussed in Art. 24.

In making standard tests it is commo
quantity of water by trying to bring the
consistency which shall be uniform for al
cements require very different quanti
reach the same consistency, and in
mortar the nature and condition of th
cause considerable variation. It shoul
that the consistency of paste does not d
upon the quantity of water used, but n

NORMAL CON

"*Significance.*—The use of
water in making the pastes *
setting, and briquettes are m
tant and affects vitally the resu

"The determination consists
of water required to reduce th
of plasticity, or to what is usu
consistency.

"Various methods have been
determination, none of which
satisfactory. The committee

"*Method. Vicat Needle A*
(Fig. 8) of a frame bearing a
at one end and at the oth
(0.39 inch) in diameter, th
weighing 300 gr. (10.58 oz.).
held in any desired position
cator, which moves over a scal

the operation by tossing it six ti
the other, maintained 6 inches a
pressed into the rubber ring throu
smoothed off, and placed on a gl
end) and the smaller end smoot
the paste confined in the ring restin
under the rod bearing the cylinder
contact with the surface and quick

“The paste is of normal consist
penetrates to a point in the mass
below the top of the ring. Great
fill the ring exactly to the top.

“The trial pastes are made wi
of water until the correct consiste

“The Committee has recommen
the consistency of which is rather
that variations in the amount of
the briquette is subjected in mou
less with such a paste.

“Having determined in this m

can recommendations, the re(
plunger shall sink to a point 6
tom of the paste for standard c(

Another method somewhat us
by the French Commission i
Boulogne method. The meth(

The paste is to be vigorous]
to bring it to the required cons

"1. The consistency of the
sensibly if the mixing be con
the expiration of the required i

"2. If a small quantity of
the trowel and allowed to fall
a height of 50 centimeters it
the trowel without leaving an
and after falling should app
without cracking.

"3. A small quantity take
into a round form until wa
should not stick to the hand

The Committee of the American
Materials in 1904 suggest the perce
following table, the percentage for
first determined by the test above gi
sistency.

PERCENTAGE OF WATER FOR CEMENT M
CONSISTENCY.

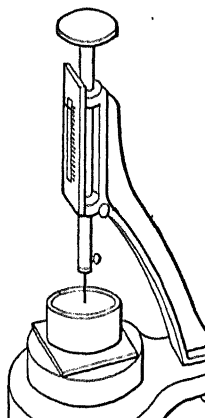
Percentage Water for Neat Cement.	Proportions Cement to Sand by Weight.					Percentage Water for Neat Cement.	Prop	
	1-1	1-2	1-3	1-4	1-5		1-1	
18	12.0	10.0	9.0	8.4	8.0	30	16.0	1
19	12.3	10.2	9.2	8.5	8.1	31	16.3	1
20	12.7	10.4	9.3	8.7	8.2	32	16.7	1
21	13.0	10.7	9.5	8.8	8.3	33	17.0	1
22	13.3	10.9	9.7	8.9	8.4	34	17.3	1
23	13.7	11.1	9.8	9.1	8.5	35	17.7	1
24	14.0	11.3	10.0	9.2	8.6	36	18.0	1
25	14.3	11.6	10.2	9.3	8.8	37	18.3	1
26	14.7	11.8	10.3	9.5	8.9	38	18.7	1
27	15.0	12.0	10.5	9.6	9.0	39	19.0	1

Testing for time of settin
two points in the process
called the beginning and
points are differently deterr
of testing, and are not m
phenomena which admit of

A method of testing for
General Gilmore and reco
of the American Society o
still quite largely used in tl
in mixing cakes of neat ce
diameter and 1/2 inch thick
observing the time when the
in diameter sustaining a wei
this as the beginning of
observations with a needle
ing a weight of one pound u
firm to bear this, when it n

The time of setting is
practice by making small c

rangement is shown in Fig. 8. I
quette of neat cement is made i
or rubber mould 10 centimeters in
timeters high, placed upon a plate
cement being mixed to a plastic con
by the consistency test. The app
that a weight of 300 grammes m



and the time when the need
through the mortar is obser
of setting; the time when
briquette without penetrat
of setting.

The accurate determina
points where the set is said
of some difficulty, as the
causes the needle to sink
than in others, and the
the circumference than in t
ever, these defects are not
exercised in mixing the m
not taken too near the ed
of set is much less well d
of set, as there is usually
which a very slight penet
insensibly to final disappea
for completion of the set
tion becomes very small, so
becomes practically horizo

set'). The former of these i
since, with the commencement o
crystallization or hardening is sa
turbance of this process may pro
it is desirable to complete the o
moulding or incorporating the
before the cement begins to set.

"It is usual to measure arbitr
end of the setting by the penetr
of given diameters.

"*Method.*—For this purpose t
has already been described in p
used.

"In making the test, a paste o
moulded and placed under the ro
graph 31; this rod, bearing the
needle, 1 mm. (0.039 inch) in
weighing 300 gr. (10.58 oz.). T
fully brought in contact with t

the collection of cement on
the penetration, while cem
area and tends to increase tl

"The determination of tl
proximate, being materially
of the mixing water, the
the air during the test, tl
and the amount of mouldin

The time of setting is
neat cement, on account o
satisfactory test with sand
quite useless when sand
interference of the grains
the needle. Rough tests o
methods may readily be r
for practical purposes, and
more nearly what may be
used. The rate of setting
indication of what the ac
different cements a mortar

employed: when the mortar w
400 grammes it is considered a
it will sustain 10,000 grammes

M. Feret has also proposed
by using fine sand composed
sieve of 75 meshes and are he
per linear inch, the test being
with the Vicat needle. This s
the effects of sand upon differen

In making tests for rate of
of the ingredients of the mor
of the atmosphere in which it
or water in which it is place
very large influence upon the
of 60° to 65° Fahr. is usuall
although the air in the laborato
higher temperature—perhaps 65

CHANGE OF TEMPERATUR

sets more quickly. The to
cement may reach 15° or 20°
it may be quite imperceptible

The change in temperat
nature of the cement, and a
connect it with the soundne
larly the presence of free lim
seem to be supported by fact
are very indefinite. Expan
action, and therefore danger
likely to cause increase in te

The test for change in tem
by placing the mortar in a
used with the Vicat needle,
which is an opening to per
thermometer. This cover p
into contact with the air or
placed, thus neutralizing the
of temperature.

Some very slow-setting ce

CHAPT

TESTS OF THE STRE

ART. 42. METH

THE strength of mortar i
ways: the tensile test is th
ployed, but compressive an
often used.

The test for tensile streng
quettes of the mortar in mou
at the middle,—in the Unit
square,—and enlarging at the

The transverse test is m
into bars, the bar is a afterv
supports near its ends, an
upon its middle, causing it

The proper conduct of a
requiring care and experie
connected with the circumst
work which have an impo
These are: the form of t
mixing and moulding; th
tempering the mortar; th
mortar is kept during the h
of applying the stress; th
the operations are perform
form results it is essential
in all of these particulars.
in this direction during rece
disparity in the results of d
due mainly to differences

Every laborator seems

materials so as to obtain
results.

"The first tests of inex
and careful persons are us
inaccurate, and no amount
the variations introduced
the most conscientious obse
ently of minor importance,
upon the results that it is
every particular, aided by
that trustworthy tests can b

Experience since the re
made has shown that the d
formity in such tests are
imagined.

The variations in the res
the work of different expe
the same method and upo
quently very large, and o
between the acceptance a

News, March 5, 1896) sho
was but 30% of the highest
quite evenly distributed b
Each result was the averag
agree fairly well among them

If the results of experien
laboratories vary so much,
tests made by less experien
of material upon temporary
fication be framed which sha
of the material? Evidently
with hand-work, the inspec
and the specifications draw
practice of the laboratory.
that some means be devised
tests may be made autom
factor eliminated in so far a

In standard tests it is cu
constant temperature of 6o
in the laboratory in which

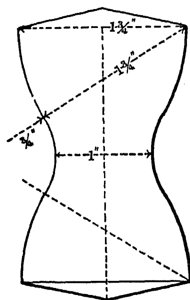
is employed. In the
are each two inche
although sometimes a
generally the standar
seven centimeters in le

The French "Com
Materials," however,
for compression specim
to so fill the corners of
ous briquettes, and th
as preferable. They
briquettes obtained by
crushing test.

For transverse test
used. Different expe
ent dimensions, and t
ably be called a stan
the adoption of this t
the acceptance of m
test-piece of a section

meters. The middle section
mm. thick, giving a cross-sect

Comparative tests of briquet
that the English form gives hig
the difference being commo
much as 30% to 40% of the
be accounted for by the fact
a sudden change of cross-se
of weakness, and while the
gradually from the ends to



meters. The use of these sn
as it admits of lighter appar
because greater uniformity i
the briquette. The work a
that less mortar is required
larger sections, so that more
from each mixing.

The size of the breakin
effect upon the strength,
much higher strength per u
ones. Thus for neat ceme
1 inch square to one 2 inc
to lessen the tensile strengt
one half that of the smaller
has shown that the strength
perimeter of the section th
the interior may be removed

M. Alexandre made a n
the relative strengths of br
He found that large briquet

"While the form of the
former Committee of the So
this Committee is not pre
other than rounding off of
radius.

"The moulds should b
some equally non-corrodi
metal in the sides to preve
"Gang moulds, which
briquettes at one time, ar
moulds, since the greater
mixed tends to produce gr

"The moulds should be
using."

ART. 44. S

Tests with sand may b
judging the value of the
probable strength of mo

obtained by washing and
obtainable, sifting the san
per square centimeter, t
particles, and by removi
by means of a sieve of 12
the finest particles. The
sieve shall be 0.38 millime
tively." The German C
specified Freienwalde sanc

In France both artifici
natural sand are used t
Commission on Methods
use of natural sand. Th
sizes:

1. Sand which passes op
by those of 0.5 mm. 2.
1.5 mm. and is retained l
which passes openings o
those of 1.5 mm.

STANDA

"The Committee recogni
standard quartz now genera
of its high percentage of vo
ing in the moulds, and its
spent much time in investiga
which appeared to be avail

"For the present, the
natural sand from Ottawa,
having 20 meshes per linear
having 30 meshes per lin
diameters of 0.0165 and o.
half the width of the openin
passed the No. 20 sieve s
when not more than 1 per ce
one minute continuous siftin

"The Sandusky Portland
dusky, Ohio, has agreed t
of this sand, and to furnish

nature of the sand; its fi
retained by various sieves
be examined under a gl
weight of a unit volum
Tests of the tensile stre
sand to be tested as con
upon standard sand are c
the value of the sand to
mortar.

Art. 45. Methods

The wide differences
of tensile tests made by d
mainly due to differen
Probably if the other st
used as that of tension
would be observable in
not only in the work of

the method of forming the briquet
used in placing the mortar in the

In making briquettes by hand
are employed corresponding to
of the mortar. The plastic met
employed, being used in Engla
United States, while the dry meth
many.

The report of the French com
tests in 1892 recommends the follo

"The moulds are placed upon
polished metal which has been w
with an oiled cloth. Six mould
gauging if the cement be slow-se
quick-setting. Sufficient material
each mould to more than fill it.
into the mould with the fingers s
and the side of the mould tapped
trowel to assist in disengaging the
excess of mortar is then removed
over the top of the mould so as to

removing them from the mould
regularity of their formation."

A method somewhat in use in
is that proposed by M. Candlo
the Commission upon Methods
use with sand mortars. It is as

"Sufficient mortar is gauged a
quettes, requiring 250 gramm
grammes of normal sand. The
sary exceeds by 30 grammes t
bring the cement alone to *norma*

The mortar is prepared in t
forming the briquette the mould
plate and a guide fitted above it
as the mould and a height of 12

"180 grammes of mortar are
distributed in the mould and
means of a metallic pestle weig
with a base of the form of the
less dimensions, the mortar is
then stronger and stronger unt

Following are the specificati
tion of German Cement Mak

"On a metal or thick-glass
paper soaked in water are l
five moulds wetted with wat
and 750 grammes of stand
thoroughly mixed dry in a
meters of fresh water are
mixed for five minutes. W
the moulds are at once filled
to be rounded on top, the r
By means of an iron trowel
centimeters long, and weigh
projecting mortar is pounde
sides, then harder into the m
elastic and water flushes to
at least one minute is nece
and pounding in of the mo
the test-pieces of the same
density at the different te
now cut off with a knife and

for five minutes. The forms a
proceed as for hand-work with s

"The mould can only be tak
has sufficiently hardened.

"The quantity of water for
setting cements must be increas

The rules recommended by
American Society of Civil Engin
lowing method of making briqu

MIXING.

"All proportions should be sta
tity of water to be used should b
of the dry material.

"The metric system is recomm
venient relation of the gramme a

"The temperature of the roo
should be as near 21° C. (70° F
maintain it.

"The sand and cement shou

by the aid of a trowel. As
absorbed, which should not re
the operation is completed b
the hands for an additional n
similar to that used in kne
affords a convenient guide
During the operation of mixi
tected by gloves, preferably

MOUL

"Having worked the pas
consistency, it is at once pla

"The Committee has been
results with the present mo
tion of machine moulding is
types permit of moulding b
and are not practicable with
recommended.

"*Method.*—The moulds s
material pressed in firmly w
off with a trowel without ra

ing briquettes by hand: first, th
thoroughly worked in gauging;
French rules require that it sha
at least five minutes, only suffic
pared at once for five or six briq
bubbles must be well worked out
the moulds. The neglect of th
much of the irregularity which
work of inexperienced operators.

It is perhaps easier to secur
the dry than with the plastic
density of the hammered brique
strength. The plastic method,
nearly with the conditions of t
in practice.

Even with the most experience
differences in the amount of wor
in forming the briquette, and the
which cause wide variations in res

In order to secure good result
is necessary that the briquettes

"A moist closet or chambe
use of the damp cloth shoul
Covering the test pieces with a
as commonly used, because
equally, and, in consequence
maintained under the same
closet is not available, a cl
uniformly wet by immersi
should be kept from direct
by means of a wire screen o

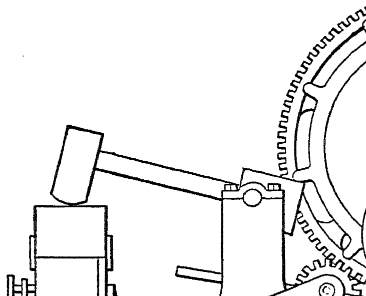
"A moist closet consists o
or a metal-lined wooden b
covered with felt and this
of the box is so constructed
sides are provided with clea
on which to place the brique
to keep the air in the closet u

"After twenty-four hours
for longer periods should b
tained as near 21° C. (70° F
be stored in tanks or pans

No entirely satisfactory system
has as yet been devised. In Euro
commonly employed for mouldin
mixing is done by hand in the ordi

In Germany and Switzerland a
sive tests are made by machine,
tensile specimens. The machine
is either the Bohmé hammer or th

The *Bohmé hammer*, designed
Charlottenburg Experiment Stati
11. It consists of an arrangement



upon the personality of the
method. The arrangement
is such that its operation mus
to give time for the hammer
being caught on the next stro
make a briquette is too grea

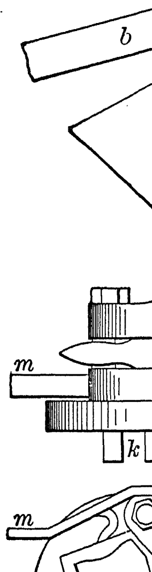
The rules of the Assoc
Makers specify this machin
order to obtain concordant
machine-making is necessa
cement and 1200 grammes
thoroughly mixed dry in a
of water are added thereto,
oughly mixed for five mi
grammes are placed in the
guide-mould, and the mou
bed-plate under the poundi
lower is placed in the form
trip-hammer one hundred a
a hammer weighing 2 kilogr
guide-mould and follower th

the number of blows by r
work to be done upon a
kilogrammeter of work pe
which the mortar is compo
ject to the same limitatio
hammer, in being very slo
pensive in first cost of appa

Canadian Method.—In
in England, the method h
the mortar quite soft, usin
with machine-mixing and
under light pressure—20
surface of the briquette.
for strength than the ordin
portant provided the resul
fications are made to agree

A number of tests made
McGill University seem t
capable of yielding uniform
tions of the individual test
series is concerned. The m

is very simple. A v
section conforms to th



in the cylinder may be subjec
175 lbs. per square inch. T
is raised above the bed-plate a
ness of the briquette (1 inch)
a triangular block (*l*) having t
section as the briquette. Th
to bring either of these holes be
one hole is in this position, ho
the cylinder at one side, and th
has been pressed into it can be
by a lever (*m*) and guided by
the pressure used the briqu
handle as soon as lifted from t
once removed and placed on
"In practical working it h
make briquettes as rapidly as
This machine may be fou
where large numbers of bric
purpose of comparing ceme
tions, as it greatly lessens the
the briquette. It is to be ol

us appliances for moulding briquettes shows
uniform results may be obtained from bri-
oulded under a single application of a steady

ethod may be applied much more rapidly
hammer method, with about as good results,
the results of different operators much more
than can be obtained by hand-work, although
ons from the mean in the work of a single
nay be as great or greater than in the hand-

es of neat cement, machine-mixed, and moulded
pressure of about 500 lbs., upon the surface
quette, give good results when the averages
t men are compared, and small variations in
re not important in the results.

nd mortar, one part cement to three parts
ressure of 1000 to 1500 lbs. is desirable to
compact the mortar to form homogeneous
and give uniformity in the results.

in the best results the mortar should be gauged
consistency that the water begins to ooze out
pressure, the cakes being reduced to a semi-
dition, and becoming too soft to handle before

aratus for making briquettes by this method
-ranged, but no satisfactory method of manipu-
briquettes so as to produce them with reasonable

For this purpose several appliances have

mixer is an apparatus in which the materials in cups with covers clamped on, and shaken and down. It has been tried in a number but has usually been found quite unsatisfac- ractice. It is difficult to make a satisfactory y this method, and the result depends very n the rapidity of operation.

ija mixer was designed and first used by Mr. England. It is shown in Fig. 13, as made Bros. Testing Machine Company, of Phila- nd consists of a cylindrical pan in which a med of four curved blades, revolves both on xis and about that of the pan. This arrange- s fairly good results in use.

shows an arrangement used by the author boratory of the College of Civil Engineering University.

apparatus the cylinder containing the materials thus avoiding the dust, which is very disa- with the open pan. The cover revolves about f the cylinder, and the gear is placed outside any danger of it becoming clogged. The ormed of vertical rods held by a horizontal arm, ves about the axis of the cylinder and also about e point of the arm.

ise any system of making briquettes by hand

le of securing good results under careful manipula-
are too slow or clumsy in operation and require
areful management to make them desirable for



FIG. 13.

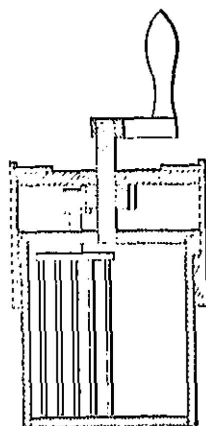


FIG. 14.

al use. The American Society Committee in 1904
t as follows upon this matter:

he Committee, after investigation of the various
anical mixing-machines, has decided not to recom-
any machine that has thus far been devised, for
ollowing reasons:

:) The tendency of most cement is to 'ball up' in
achine, thereby preventing the working of it into a
geneous paste; (2) there are no means of ascertain-
vhen the mixing is complete without stopping the

or tensile strength is commonly made by riquette in a pair of clips which catch its attached to a machine by which the load break the briquette may be weighed. In re uniform results it is necessary that the e so applied as to bring the tension axially

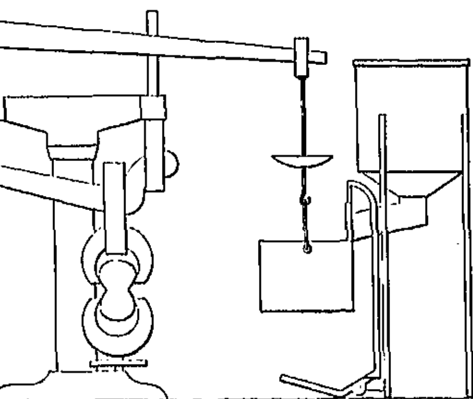


Fig. 15.

all section of the briquette, and also that the ration of the load shall be always the same. various types of testing-machines in use, s unnecessary to enter into any detailed f them here.

aelis machine, shown in Fig. 15, consists of rs suspended from the framework carrying ne clips which hold the specimen and at the

of Michaelis. In the Fairbanks machine the shot ghed and the stress determined by the same beam in breaking the specimen, the bucket being hung other end of the beam from that used in breaking pecimen, and the weight found by means of a sliding t, the beam being graduated to read stress upon the ette.

e *Riehlé Machine*, shown in Fig. 16, is an ordinary machine in which the load is brought upon the nen by means of the lower hand-wheel, while the t is moved along the scale-beam by the upper wheel. In testing a briquette both wheels must be ted simultaneously and the scale-beam be kept ced.

e *Olsen Machine*, shown in Fig. 17, is similar in cter to the above, but differs somewhat in detail. machine has been modified by Prof. Porter in onstructed for Lafayette College, by adding a sec- lever below the clips, through which the stress is ed by means of water flowing into a bucket attached end. The stress is measured by the weight sliding the upper scale-beam as in the ordinary machine, he weight is moved automatically by means of an ic contact at the end of the beam.

rious modifications of these machines and others of complicated type are frequently employed. Nearly of the machines in common use may give good results actice. In selecting a machine, however, those are

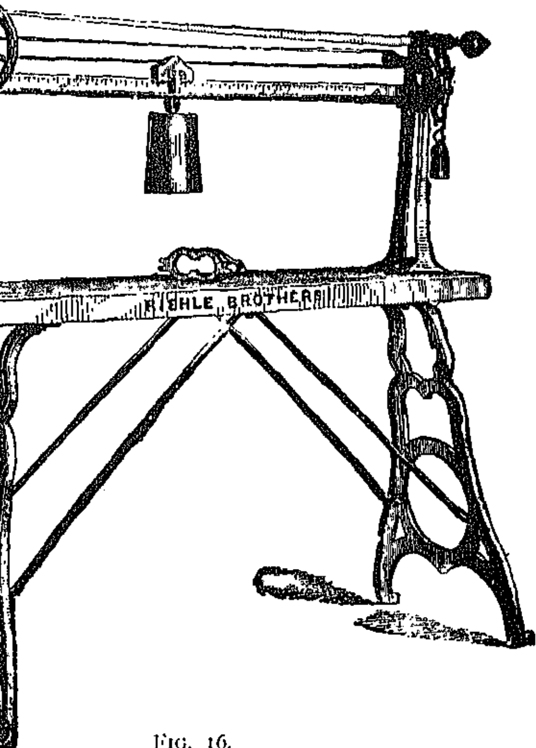


FIG. 16.

hat the stress upon the briquette shall be
must be exercised in properly centring the
the clips, and the form of the clip must
it shall not clamp or bind upon the head
ette, but may be free to adjust itself to an

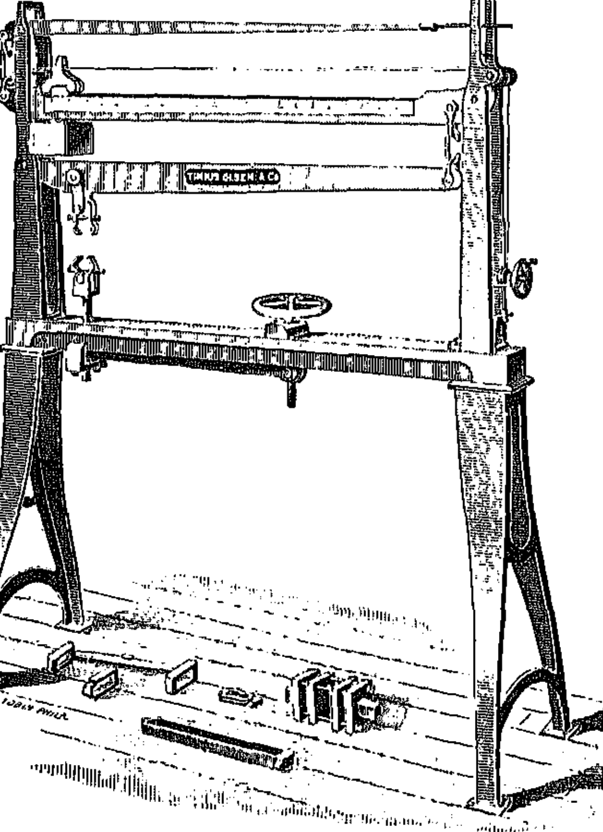


Fig. 17.

yet as small as possible to admit of its more free
djustment. The suspension of the clips, as is
, by conical bearings permits them to turn so as

an briquette. As here given it is approved
ssion des Méthodes d'Essai des Matériaux
n," as giving very satisfactory results.

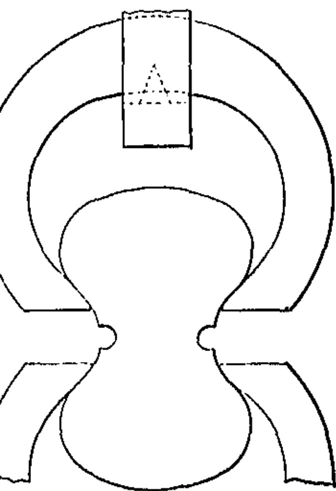


FIG. 18.

uette used in the United States and Eng-
rms have been used for clips. Fig. 19
adopted by the Committee of the American
Engineers in 1885. This form does
ent bearing-surface for good results, as
ikely to break on account of the crushing
f the briquette at the point of contact.
wn in Fig. 20 has been much used, but
tage of clamping the head of the briquette
unless great care is used may cause the

points of contact irregularly to the small section,
break due to twisting may often be a centre break,
irregularity show only in the results.

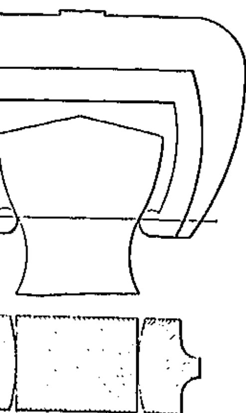


Fig. 19.

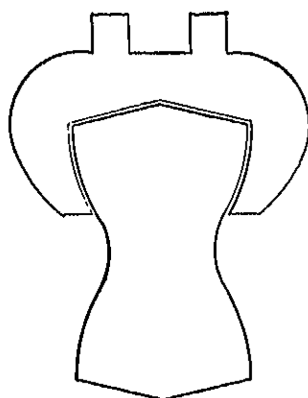


Fig. 20.

form of clip shown in Fig. 21 is recommended by
committee of the American Society of Civil Engineers
This form is a decided improvement over the
forms, but seems to give rather too small area of
between the briquette and clips for the best
It avoids twisting the briquette and permits
ory adjustment to axial stress.

der to prevent crushing at the points of contact
permit more free adjustment Mr. W. R. Cock
posed * a rubber bearing, as shown in Fig. 22.

* *Engineering News*, Dec. 20, 1890.

pliances have been proposed for the accu-
of briquettes, or to prevent the more free
f the clips to the direction of stress, by

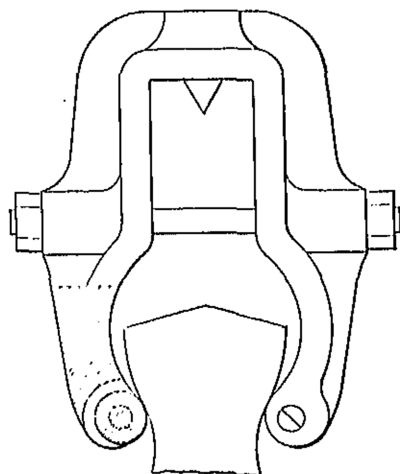


FIG. 22.

ate for the exact placing of the briquette,
g the clips at the upper corners. These
do not, however, seem to be necessary.
nittee of the American Society of Civil
1904 made the following recommendations
ts for tensile strength:

may be made on any standard machine. A
lip is recommended. This clip is to be

l from the water. Care should be observed in ng the briquette in the testing-machine, as cross-s, produced by improper centring, tend to lower reaking-strength. The load should not be applied uddenly, as it may produce vibration, the shock which often breaks the briquette before the ultimate th is reached. Care must be taken that the clips he sides of the briquettes be clean and free from of sand or dirt, which would prevent a good bearing. oad should be applied at the rate of 600 lbs. per e. The average of the briquettes of each sample should be taken as the test, excluding any results are manifestly faulty.

ART. 48. COMPRESSIVE TESTS.

e compressive strength of cement-mortar is much er than its tensile strength, and as it does not seem re a better indication of value, while more difficult tisfactory determination, and also requires heavier ratus, it is not usually employed as a test of quality e acceptance of material. The compressive test is, ver, valuable for purposes of comparison, and is able as an addition to the showing made by the tensile In the European experiment stations it is customary t all cements under compression as well as tension.

cause the material to spread laterally by
e sides, failure usually occuring by shearing
inclined at about 30° with the vertical,
idal or conical blocks at the middle.

pecimen is small in height the resistance
unit area than if it be higher, and for blocks
m the resistance increases with the size.
mmonly employed for this purpose, but
sometimes preferred, on account of the
ith which homogeneous specimens may be
because of the liability of the corners of
off under comparatively light pressure.

on piece in Europe is a cube with edges
long, moulded under the hammer, and
is required that the pressure be always
o faces of the cube, that is, on the faces
inst the surface of the mould, in forming

n conference at Berlin, however, recom-
se of blocks 5 square centimeters in area,
ne tensile specimens.

n "Commission on Methods of Testing
ade the following recommendations:

of compressive strength the half-briquettes
tension are to be used. Each half-bri-
crushed separately, and the sum of the two
as the strength of the specimen.

sence of half-briquettes, cylinders 45 milli-

stone surface."

e testing apparatus should be so arranged that ess may be continuously applied at such a rate rush the half-briquette in one or two minutes."

r tests having for their object the comparison of with other materials, it is provisionally recom- d to employ the cube, with faces of 50 square centi- area, placed upon one side. These tests will thus n in a general way to the rules adopted for the naterials."

he United States it is common to employ 2-inch for this purpose, although some laboratories use ers of about the same area and somewhat greater

making compressive tests of cement, any of the ry lever or hydraulic machines in common use, capacity of 40,000 to 50,000 lbs., is usually suffi- It is desirable that the load be applied as uni- as possible, as the result will be more or less d by unsteadiness or shocks.

as been proposed to employ punching tests instead shing the entire specimen. This method has been yed for a number of years in the laboratory at France. A punch five square centimeters in section ar) is employed, and it is claimed that the results ore regular than those obtained by crushing the specimen, while requiring less force in the testing- ne. The "Commission des Méthodes d'Essai des

the strength of mortar under transverse
seldom employed as a measure of the quality
erial, but are frequently made with a view
ing the action of the material in service.
have often been made to substitute the trans-
e tensile test in the reception of material.
estions have usually been based upon the
the test and of the apparatus with which
arried out. All that is necessary, after the
red, is the arrangement of a couple of knife-
which the ends of the bar may be rested, and
e-edge to carry the weight brought upon the
e bar. The ordinary test by tension is, how-
simple, and there seems to be little if any
n making a change, although the transverse
an equally effective means of determining
uch less is known as to what the transverse
ould be, and its use in specifications would
preceded by experiments to obtain proper
he loads to be required, while the errors due
s in making briquettes would exist the same
case as in the other.

rand-Claye made a large number of tests to
nsile and transverse strength for both neat
mortars in small test-pieces. He used
meters square and 12 centimeters long, and
es of the ordinary 5-square-centimeter sec-

of section), were found to average a little
e the unit stress for tension. The use of this
is instance is of course inexact, as it assumes
to have the same coefficient of elasticity for
compression, and to be strained only to the
As all the specimens are of the same size, how-
nmaterial for purposes of comparison.

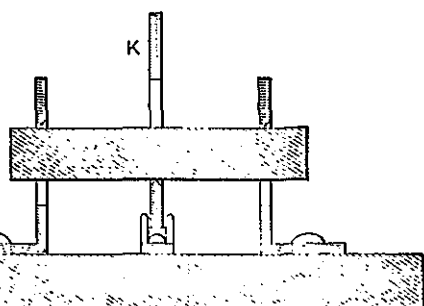


FIG. 24.

the transverse test the most common method
provide supports for the ends of the bar
eights directly upon its middle. Care should
to guard against the crushing of the material
nife-edges; a good plan is to use small plates
ween the knife-edge and the surface of the
distribute the load.

ension-machine is in use, a transverse attach-
ily added, by which both tests may be made
machine. Fig. 24 shows such an attachment

nall specimens for transverse tests it is
ifficult to handle the test pieces without
and, in general, if fairly accurate results
the tensile test is more easily handled.

Factors Affecting Strength Tests.

ointed out small differences in the manipu-
surroundings of the material during the
an important influence upon the results
rength of cement.

.—The effects of variations in temperature
erent cements. In general, mixing at a
re of air and materials results in a greater
s obtained by mixing at a high temperature,
eing greater for quick-setting materials. It
prescribe a temperature between 65° and
tandard tests. Lowering this temperature
will sometimes increase the strength on
s 20%, while increasing the temperature
nay correspondingly diminish the strength.
rather quick-acting materials, mixing with
will practically ruin the mortar.

er hand, within the limits of ordinary air
briquettes kept at high temperatures dur-
period of hardening usually show greater
those kept at low temperatures. There is,

onsistency. The quantity of water to be used in king briquettes is determined for standard tests by ing the quantity necessary to give normal consistency, described in Art. 40. Variations in the quantity water may very materially affect the strength upon rt-time tests. As a rule the use of a comparatively mixture, provided the paste be throroughly mixed well compacted in the moulds, gives higher results short-time strength tests than if a wet mixture be ployed. This difference may largely disappear in s made after longer periods of time. With some quick-ng materials the quantity of water given by the nor-l consistency test is abnormally large, and changes terially the action of the cement from what it would with less water. In one instance a cement mixed h about 25% water gives a rather dry paste, setting en or twelve minutes, and giving fairly good strengths one and seven days. For normal consistency, this nent requires over 40% of water, and mixed with s quantity, sets in about six or seven hours, and has no ength at one day and very little in seven days. After months both samples show good strength. Where h materials are to be used some modification of thod is desirable.

Moisture.—Cement briquettes kept damp during setting l the early period of hardening show much greater ength than those kept in dry air. It is usual to place briquettes in a damp-closet for the first 24 hours

the first period. This requires considerable
e good results, as unequal or premature
cloths may materially affect the results of

of variations in the moisture conditions are
for all cements, some natural cements acting
tly from the usual rule, and not requiring
sphere for the development of early strength.
ong time tests are made the greatest strength
veloped by taking the briquettes from the
eping dry during the later period.

of Water of Immersion.—The nature of the
ch briquettes are kept has been found in
es to materially affect their strength. A
40% has been obtained between briquettes
ater and in water which had stood in the
long period without change. The water
should be frequently renewed when running
available.

nce of carbon dioxide in the water seems
proper hardening of the mortar. In distilled
briquettes will disintegrate. Nearly any
water which has been well aerated will
ults.

value of a cement as showing the possession of active elements. There are, however, different ients which act at different rates, and it is unwise classify cements according to strength alone. The ile strength developed by cement in a test extend- over a short period of time is not necessarily an cation of the strength that may be attained by it ing a longer period, unless the normal action of the ticular material be known. That which is strongest irst may not continue to be the strongest.

'he development of good strength soon after the of the mortar is a desirable attribute in most engineer- work, and the probability of the material being d is greater where it shows a fair early strength, therefore it is usually wise to specify that the cement ll develop a fairly good strength on a short-time test, there is no object in requiring extremely high values. Ir. Faija recommends that the gain in strength ween the 7- and 28-day periods be considered rather n the absolute early strength in determining the bable subsequent gain in strength. This is doubtless etter guide than the usual one, but it is not usually cticable to require tests extending over a period of days, and in many instances it would be misleading, omparison of different cements were attempted.

'rof. Unwin gives a formula for the strength at any iod, $y = a + b(x-1)^n$, in which y is the strength at x eks after mixing, a the strength at end of one week,

s the value $n = 1/3$ for Portland cement in
l shows that the formula gives values well
vith the results of tests in many instances.
owever, accurate for general use, as is shown
e when applied to many long-time tests.

es to be required in specifications need to
l, especially with the natural cements, to
the particular kind of cement to be used,
th the practice of the laboratory.

rge quantities of cement are regularly em-
the same men continuously make the tests,
paratively simple matter to conform the speci-
the work of the laboratory so as to get reliable
of the value of the material. A very large
the testing for reception of material must,
e done upon detached works, where temporary
are to be used and inspectors employed
asion. In these cases it is a difficult matter
specification which shall give good results,
operator can himself first be calibrated.

ults of tests in the permanent laboratories
e higher strength for the same material than
obtained on an ordinary outside test, espe-
a comparatively inexperienced man. It is
inferred, however, that the highest results
arily the outcome of the greatest skill. As
most expert and reliable operators get only
trength for the best material.

g inferior material rejected on an ordinary test
d it to one of the laboratories known to obtain
mally high strengths, and thus get results which
to show error on the original test.

e American Society for Testing Materials has recom-
ed the following as the range for minimum values
cifications for tensile strength of briquettes 1 square
n section.

NATURAL CEMENT.

Neat Cement.	Strength.
urs in moist air.	50-100 lbs.
ys (1 day in moist air, 6 days in water) ..	100-200 "
ys (1 " " " " 27 " " ") ..	200-300 "
One Part Cement, Three Parts Standard Sand.	
ys (1 day in moist air, 6 days in water) ..	25- 75 "
ys (1 " " " " 27 " " ") ..	75-150 "

PORTLAND CEMENT.

Neat Cement.	Strength.
urs in moist air.	150-200 lbs.
ys (1 day in moist air, 6 days in water) ..	450-550 "
ys (1 " " " " 27 " " ") ..	550-650 "
One Part Cement, Three Parts Sand.	
ys (1 day in moist air, 6 days in water) ..	150-200 "
ys (1 " " " " 27 " " ") ..	200-300 "

specifications it is usually desirable to require
showing a fair degree of strength rather than very
values. The latter are if anything less likely to
good material and unnecessarily limit competition.

CHAPTER VII.

...ESTS FOR SOUNDNESS.

...ART. 52. ORDINARY TESTS.

...is the most important quality of a cement, ...e power of the cement to resist the disinte-...nces of the atmosphere or water in which ...aced. Unsoundness in cement may vary ...gree, and show itself quite differently in ...rial. Cement in which the unsoundness ...aced is apt to become distorted and cracked ...ys, when small cakes are placed in water. ...ch the disintegrating action is slower may ...visible change of form, but after weeks or ...ally lose coherence and soften until entirely

... in common use for testing unsoundness ...all cakes or pats of neat cement, usually ... inches in diameter and 1/2 inch thick, ... of glass, and keep them in air or water ...s, carefully watching them to see if they ...ns of distortion or surface cracks, which ... tendency to disintegration.

...n standard specifications require that the

r a period of 28 days, when, if no cracks or distor-
s appear, the cement is considered sound.

The cakes, especially those of slow-setting cement, st be protected against draughts and sunshine until r final setting. This is best accomplished by keep- them in a covered box lined with zinc or under cloths. In this manner the formation of heat cracks avoided, which are generally formed in the centre he cake, and may be taken by an inexperienced person cracks formed by blowing."

'he French Commission upon Methods of Testing terials recommend both a pat test and test of the ount of swelling which takes place in the mortar, follows:

"*Cold Tests.*—(*a*) For this test the cement paste is ned into a pat about 10 centimeters in diameter l 2 centimeters thick, made thin at the edges.

"Immediately after being made the specimens intended tests in water are immersed in the same conditions the briquettes used for tensile tests.

"The specimens intended for use in the air are at e exposed to the conditions indicated for briquettes."

"The condition of the specimens is observed at the ne periods of time employed in making tensile tests days, 28 days, 3 months, 6 months, 1 year, etc.).

"(*b*) To measure the increase in volume of the mortar neat cement after prolonged immersion in cold water, bar of cement is employed 80 centimeters in length and

of the bar of mortar." (See Fig. 25.)
of testing by measuring the variation in
ed to some extent in Germany. Methods
his test are described in Art. 53.
nt in testing soundness in this manner
ould be continued over as long a period
d many cases of unsoundness are not
a 28-day test. Instances have been
ch mortar in the form of 2-inch cubes
disintegrated within two years, where
ng was not observable for three months
test. The most common and dangerous
ndness are probably discovered by the
It may be observed, however, that the
gration of mortar is not oftener observed
tions is probably due more to the general
the cement supplied by the best makers,
uent stability of work regardless of the
ortar, than to the efficiency of the test for

of water to be used in mixing mortar
ndness is about the same as that used
ngth, although a variation in the quan-
ll limits does not seem to materially
esults. Care must be taken that the
moist during setting and previous to
rder that they may be free from drying
s account the French commission con-

gh apparently quite sound in water if first allowed
n air.

n mortar is to be used in sea-water, the pats of
are placed in water of the same character, and
rly as possible corresponding to the conditions
tice.

tically, however, the action of sea-water is so
hat the test is comparatively useless. M. Alex-
found * that the first indication of disintegration
ot be shown for several months or perhaps years.
o *found* that the action in the *laboratory did not*
accord with that in the work. This was probably
failures occurring because of the method of em-
the mortar, when the cement was not defective.

are sometimes made of mortar to be used in
er *by causing the water to filter through* the
of mortar under pressure. This test is made
nce by employing the standard cubes used in
ssion, which are arranged and submitted to
n as in the test for permeability (see Art. 67).
blocks are afterward crushed, and their strengths
ed with those kept under normal conditions.

Art. 53. Measurement of Expansion.

undness in cement is doubtless for the most
ue to the presence of expansive elements, the
of which subsequent to the setting of the cement

Annales des Ponts et Chaussées, Sept. 1890, p. 131.

r when present in sufficient quantity, or by crease in volume without visible distortion in less quantity, or when more finely divided ly distributed through the mass.

e efficient and accurate method of deter- presence of expansives than is afforded by on of thin pats of mortar, various appliances evised for the purpose of measuring directly of volume of a block of mortar.

-bar Apparatus.—The first apparatus for of measuring change of dimensions was MM. Durand-Claye and Debray. It has for a number of years in France, and was l for use in cold tests by the French Com- Methods of Testing Materials (see Art. 52). tus is shown in Fig. 25. The test is made o centimeters long and 12 millimeters square The moulds in which these bars are formed on rods considerably longer than the bars to nd of section 30 by 12 millimeters, laid flat , held apart at the ends by blocks of the same e cement bar, and prevented from spreading t the ends.

g the test, the bar of cement is placed in a tube 80 centimeters long and 23 millimeters closed at the bottom and filled with the action of which the mortar is to be exposed.

f the cement bar is thus multiplied by 10

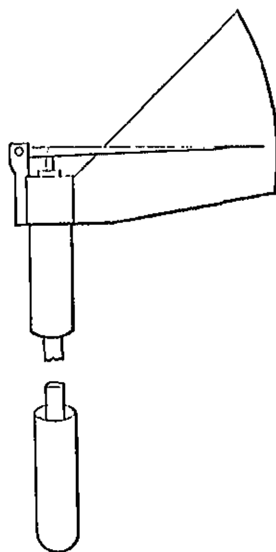


FIG. 25.

ing on the arc, which may be graduated, and
ve positions of the needle read from the scale,
e covered with blank paper, and have the posi-
needle-point marked and afterward measured.
od requires much care in manipulation, both
the bars and in handling them in the test.

ger's Caliper Apparatus. — This apparatus,
y Prof. Bauschinger and used in the German
laboratories, is an arrangement for measur-

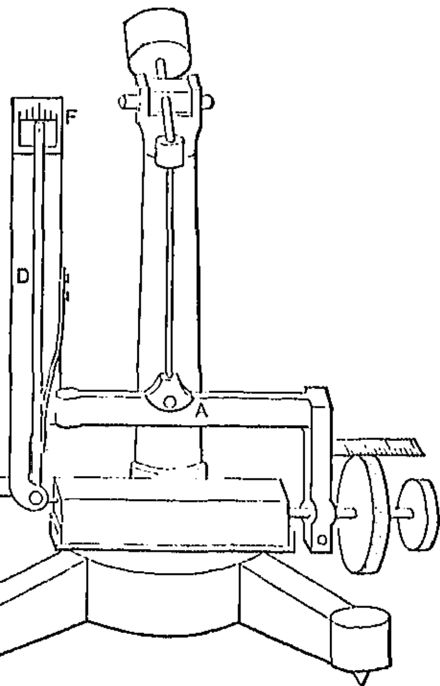


FIG. 26.

oulded with square cavities in the ends
n which are set small plates containing
n bearings for the points of the microm-
he change in length may be measured
eter.

ng apparatus is suspended by a rod from

ertical bar at the bottom of which is hinged the needle
The lower end of the needle has a point which is
ssed by a spring against the end of the specimen in
ing a measurement. The pressure of the micrometer
inst the specimen is regulated by bringing the point
he needle to zero on the scale *F*. A small bar of metal
ased in wood is used as a standard in calibrating
instrument, the length of the standard being known
y accurately at a definite temperature.

e Chatelier's Apparatus.—The apparatus of Prof.
Chatelier is designed to measure the increase in
cumference of a cylindrical block of mortar. This
thod is recommended by the French commission
use in making hot tests, and is said to have the ad-
ntage of being much more easily manipulated than
other methods. It has also been suggested that
increase in length for long bars may not be an accurate
lication of the actual swelling, as there would be a ten-
ncy for the expansion to take lines of least resistance,
l therefore the transverse swelling may be more than
longitudinal.

This apparatus is shown in Fig. 27. It is described
Prof. Le Chatelier as follows: * "A much more simple
d yet sufficiently precise measurement of the expansion
n be made by letting the cement harden in cylindrical
oulds of a dimaeter equal to their height (for example

* Trans. Am. Inst. Mining Eng.

nt, not of the diameter, but of the circum-
e cylinder of cement. Very slow-setting
nes, the water of which would evaporate or
air, it is indispensable to immerse as soon

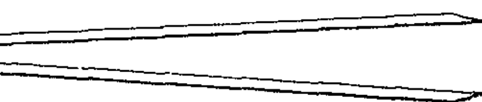


FIG. 27.

ithout waiting for them to set. The immer-
of a porus mass filled with air may some-
on of capillary phenomena, give rise to a
ion, and even to more or less disintegration
ss be insufficient. During the moulding
setting has taken place the mould should
by means of a suitable holder, which is
setting and before the measurements are

cts of good quality, the distance between
ne needles does not attain 1 mm. in 28 days
of the end of setting. This test for invari-
ne, when made cold, has but little interest,
s only exceptionably bad products."

hat many cases of unsoundness in cement
by the ordinary tests when extended over
d of time has long been recognized, and
have been made to find some means of
with accuracy and within a reasonable
the material be reliable. The difficulty
material of so variable a nature, and in
may be due to so many and so diverse
f-evident. Each test must be directed to
ation of the presence of some particular
undness, and all of them seem, when in-
applied to all cements, to meet material
pass them, although of good quality, and
are evidently inapplicable.

of these tests are directed to the detec-
called expansives, and most of them attempt
he chemical action, which causes the swelling
ution, by the action of heat. Some of
ave proven fairly successful in use, although
extensively employed as tests for the recep-
l.

ere first suggested by Dr. Michaelis, who
use of heat to advance the hardening of
a view to determining, from the strength
hort time in hot water, that which would
ger period under normal conditions. From
ments in this direction it appeared that the
d in from 1 to 7 days in hot water might
relation to those obtained in much longer

even showing a loss of strength in hot as
cold water.

of tests made by M. Deval it was found
tion of a small percentage of quicklime
rtland cement caused the cement to attain
when kept in hot than in cold water, and
telier proposed to utilize this discovery for
presence of free lime. He suggested the
tes of 1 to 3 mortar, and the comparison of
of briquettes conserved for 3 and 7 days
° C. with those kept for 7 and 28 days in
nary temperatures; the cements of good
ow a strength a least equal in hot to that
d water.

observed in considering this test that there
od cements which give less strength hot
n of normal quality. M. Alexandre found
rich in aluminates behave in this manner.
certain cements which give high tests in
twithstanding the presence of appreciable
expansives. These are apparently silicious
w hydraulic index, in which the free lime
g the cement unsound does not cause it to
n hot water during the short period of the

several methods of testing the soundness
the aid of heat, which have come more
e, and have in many instances given satis-

pansion as in the corresponding cold tests. Descrip-
of these tests are given in the following articles.

Art. 55. Kiln Test.

s test was originated by Dr. Bohmé, and consists
osing small cakes of the cement to heat in a drying
or a definite period, and observing whether it cracks.
specifications of the Association of German
nt Makers recommend this test as a means of
g an opinion quickly, but make the ordinary 28-
st decisive as to those cements which fail to pass
ln test. In these specifications the kiln test is
bed as follows:

r making the heat test, a stiff paste of neat cement
ater is made, and from this cakes 8 cm. to 10 cm.
meter and 1 cm. thick are formed on a smooth
neable plate covered with blotting-paper. Two
se cakes, which are to be protected against drying,
er to prevent drying cracks, are placed after the
of twenty-four hours, or at least only after they
et, with their smooth surfaces on a metal plate and
d for at least one hour to a temperature of from
C. to 120° C., until no more water escapes. For
urpose the drying closets in use in chemical labora-
may be utilized. If after this treatment the cakes
no edge cracks, the cement is to be considered in
l of constant volume. If such cracks do appear, the
t is not to be condemned; but the results of the

n more than 3 per cent of calcium sulphate
other sulphur combinations."

is considered by some authorities to be of
nents to be used in the air. It differs very
wever, from the way the material is used in
it effects the complete drying out of the
many instances also it is very difficult to
consequence of the loss of cohesive strength
g, where no distortions appear. The effect
rawal of the water necessary to the proper
the mortar may vary as the rapidity of action
ial varies.

test has sometimes been modified by using
osphere in place of dry air. A pan of water
he oven under the specimens; the evaporation
eep the air saturated with moisture. Prof.
sed this method in a series of comparative
und it to give results similar to those of his
but somewhat less effective. His method
vs: "The specimens are placed on a support
on the bottom of which are several milli-
ater. The heat is gradually applied so as to
l the water in three to six hours,—first that
the bottom of the oven, then that which has
ed by the mortar. Until the water is entirely
he temperature remains at about 95° C. The
ontinued a half-hour after the disengagement
r ceases, in such manner as to raise the tem-

lt to render the results comparable. It is not possible make the duration of heat exactly the same for all the ecimens, and after the evaporation of the water the heat the *bottom is much greater* than at the top of the en."

Flame Test.—A dry-heat test has been proposed and sometimes made in Europe, by making a ball of the nent paste about two inches in diameter and placing on a gauze in the flame of a gas-jet. The heat is dually applied, so that at the end of an hour it reaches emperature of about 90° C. The heat is then increased il the lower part of the ball becomes *red-hot*, after ich it is cooled and examined for cracks. The ults of this test are much like those of the dry-kiln , and are usually difficult to interpret satisfactorily.

ART. 56. STEAM AND HOT-WATER TEST.

This test consists in subjecting cakes of cement, preed in the ordinary manner, to the action of steam three or four hours, then immersing in hot water the remainder of twenty-four hours, and examining cracks and distortions.

Mr. Faija, by whom this test was devised, uses it his specifications for cement in England. He describes method of conducting the test as follows:

Briefly, it is a vessel containing water, the water being ntained at an even temperature of about 110° to ° Fahr.; there is a cover to the vessel, so that above

a rack in the upper part of the vessel, and
upon the by warm vapor rising from the
en the pat is set quite hard, it is taken off
put bodily into the water, which, as has
stated, is maintained at a temperature
5° Fahr., and in the course of twenty-four
ken out and examined, and if found then
ard and firmly attached to the glass, the
be at once pronounced sound and perfectly
f, however, the pat has come off the glass
icks or friability on the edges, or is much
under side, it may at once be decided that
its present condition is not fit for use."

prefers the temperature given above, but
nenters have seemed to get better results
ner one. Prof. Tetmajer obtained fairly
with a temperature just below the boiling-
200° Fahr. He subjected the cakes to the
am for four hours, and hot water twenty
g the cakes in the steam as soon as mixed.
y modified this method of testing, and
into the specifications of the Department
w York City. Four pats or cakes of cement
he usual manner were used by Mr. Maclay
he conduct of which he describes as follows: *

s, American Society of Civil Engineers, vol. XXVII.

the steam-bath after double the interval has
it took the pats to set hard, counting from the
ging. The fourth pat is placed in the steam-
end of twenty-four hours.

st four pats are each kept in the steam-bath
, then immersed in water of a temperature
oo° Fahr. for twenty-one hours each, when
aken out and examined. To pass this test
ll four pats, after being twenty-one hours in
should upon examination show no swelling,
distortions and should adhere to the glass
he latter requirement, while it obtains with
nts nearly free from uncombined lime, is not
on, the cracking, swelling, and distortion of the
much the more important features of this test.
-water tests, where the cement is very objec-
om excess of free lime, improper burning, or
es, the trouble generally shows itself in the
distortion of all four pats. Where the cement
ad the cracking and swelling takes place in the
pats only, and when the cement is still less
ble only the first two pats crack or swell.
ing or swelling of No. 1 pat alone can generally
rded.

ery case of failure and rejection the cement
e been allowed to set hard in a normal tempera-
e subjecting it to a steam-bath."

ld be noted that the effect of exposing the

setting is greatly increased by the heat of the test may be augmented by placing at once; but where the rate of setting is the heat may cause the action of the expan- lace before the set, thus lessening the severity In most cases the result of the test is the ray, but it seems fairer to permit the cement submitting it to the test.

y, however, in his specifications does not sults of the steam and hot-water test as con- se of failure, but only considers it as cause of the cement failing to pass it, and adds t for the purpose of apparently giving the one more chance. This test consists in rength of briquettes conserved in hot water ng them with those kept cold.

riquettes are prepared and treated as fol- making the briquettes for the ordinary cold- four additional sets of five each of neat four additional sets of mortar, one part two parts sand, are prepared, and allowed y-one hours in moist air of about 60° Fahr. aced for three hours in a steam-bath about hen immersed in water maintained at 200° which they are broken when two, three, four, ays old respectively, and the breakings com- he normal breakings of briquettes seven and days old kept in cold water."

old, and the hot-water seven-day breakings cement are nearly as high as the normal -day breakings cold, *where the cement is of*. Where the cement is poor, and the pats ng and distortion, there is generally a re-*lling off in the strength of the hot-water bri-* the above comparison., and one system can used as a check on the other."

ractically the same test mentioned in Art. osed by M. Le Chatelier. Its use in this ecommended by M. Candlot:

ents which contain free lime show less resist- water than in cold. The cements of good ot water show resistances equal to or greater n cold. Cements properly proportioned and s, but not completely burned, give, in this tory results."

y pointed out, however, the relative strengths l do not depend altogether upon the presence s, and it is questionable if this method is as that it is designed to check. Some unsound rtainly give high results in the measurements gth of briquettes conserved hot, while there no authentic instance of any unsound cement ted on the steam and hot-water test, although t may perhaps be condemned.

er of Zurich. It consists in placing the tested in cold water, and then gradually emperature of the water to boiling. Prof. ethod is to place the pats in cold water im- er gauging, raise the temperatue to boiling hour, continue boiling for three hours, and the pats for checking and softening.

od seems rather more severe in its effects rtar than the other hot tests, although in ing but little from the steam and hot-water boiling temperature is employed in that ion, however, seems to be more energetic, is required to arrive at the same results.

esirable in using the boiling test to permit o set before subjecting it to the test, as giv- eliable indication of value. The results of in most cases practically the same whether as previously set or not. When cement is the boiling test before setting takes place it to exercise much care in the manipulation avoid any disturbance of the mortar through of the water when heated. The results of depend somewhat upon the rate of setting al, and upon the influence of heat upon the g. With quick-setting cements this action nt, but with those very slow the heat may on of the expansives to take place in advance ng, or the ceent may romain soft until late

s method is to roll a ball of the mortar, and
the ball to the required thickness. The con-
the mortar is determined by the requirement
ll not crack in flattening or run at the edges.
n boiling water this seems desirable, but for
used in the ordinary cold tests the thin edges
ntage in expediting the results where unsound-
in the mortar.

ing test is frequently used in connection with
for measuring expansion, in place of observ-
stortions or cracks. The Bauschinger caliper
is sometimes employed in this way, the bars
ected to the boiling test, and the increase in
ed. The Le Chatelier apparatus (Fig. 27) is
ly employed in this manner. The French
upon methods of testing materials recom-
use of the Le Chatelier apparatus for this pur-
ddition to the cold test given in Art. 52, as

'ests.—For these tests cylindrical test-pieces
yed, 3 centimeters in diameter and 3 centi-
h, made in metal moulds 1/2 millimeter thick,
generatrix, and carrying, one on each side of
o needles, 15 centimeters long. The increase
ance between the ends of the needles gives a
the swelling.

oulds as soon as they are filled are immersed
vater. After an interval of not more than

...ree for six hours, and then it is allowed
...aking the final measurements."
...od of testing is not applicable to quick-
..."
...ard test for deformation is to be made
...ent of standard consistency."
... Standard specificiations adopted in 1904
...st for Portland cement, conducted in the
...as prescribed by the French specification
(See Appendix.)
... test is more simple than the steam and
... and requires very little in the way of
... may readily be made anywhere without

Art. 58. Pressure Test.

...ger has devised a high-pressure steam test
... In this test the pats are allowed to
...ee days, and are then exposed to steam
...t a pressure of from 3 to 20 atmospheres.
... has used this test for a number of years,
... it gives very satisfactory results, and that
...carried out it enables a complete and rapid
... formed on a cement containing magnesia.*
... accelerated tests, there has been much
...he reliablity of this one, some authorities
...many of the best Portland cements fail

...ciety of Chemical Industry, vol. XII, p. 927.

test is executed both upon the neat cement and
nortar, the severity of the test being greater upon
at cements. Dr. Erdmenger claims that the best
ts show no defect under this test at high pressures
atmospheres); that others may show defects at
ressures, although safe in practice (especially in the
est), but they are not first quality; while cement
cannot stand the pressure test of about twelve
pheres in the sand tests should be rejected as faulty.

Art. 59. American Standard Tests.

erican Specifications commonly impose only the
oat test for soundness, although in a number of
ces the steam and hot-water test (Art. 56) is em-
l. In a few specifications the boiling test (Art.
ith thin edged pats, is used.

Canadian Society of Civil Engineers, in 1903,
mended the following:

Blowing test.—Mortar pats of neat cement thor-
y worked are troweled upon carefully cleaned 5-inch
-inch ground-glass plates. The pats shall be about
thick in the centre and worked off to sharp
at the four sides. They shall be covered with a
cloth and allowed to remain in the air until set,
which they shall be placed in vapor in a tank in
the water is heated to a temperature of 130° F.
remaining in the vapor six hours, including the time

samples shall break with a sharp, crisp ring.
ittee of the American Society of Civil Engi-
) recommended the following:

ce.—The object is to develop those qualities
o destroy the strength and durability of a
it is highly essential to determine such
nce, tests of this character are for the most
a very short time, and are known, there-
rated tests. Failure is revealed by cracking,
lling, or disintegration, or all of these phe-
cement which remains perfectly sound is said
ant volume.

—Tests for constancy of volume are divided
es: (1) normal tests, or those made in either
maintained at about 21° C. (70° F.), and
ed tests, or those made in air, steam, or
emperature of 45° C. (115° F.) and upward.
es should be allowed to remain twenty-four
st air before immersion in water or steam,
on in air.

e tests, pats, about 7½ cm. (2.95 inches) in
cm. (0.49 inch) thick at the centre, and taper-
edge, should be made, upon a clean glass
10 cm. (3.94 inches) square], from cement
mal consistency.

est.—A pat is immersed in water maintained
C. (70° F.) as possible for twenty-eight days,

mperature and observed at intervals.

ated test.—The pat is exposed in any conve-
n an atmosphere of steam, above boiling water,
closed vessel, for three hours.

s these tests satisfactorily, the pats should
n and hard, and show no signs of cracking,
or disintegration.

the pat leave the plate, distortion may be
st with a straight-edge applied to the surface
in contact with the plate.

present state of our knowledge it cannot be said
t should necessarily be condemned simply
o pass the accelerated tests, nor can a cement
red entirely satisfactory simply because it
these tests.

0. Value of the Accelerated Tests.

ability of the various accelerated tests for
the soundness of cement in use is a matter
which there is much dispute amongst au-
the subject. These tests have not as yet come
l use, and considerable opposition has been
o them, although in certain instances they
ed.

stion of adopting the accelerated tests was
y the Association of German Cement Manu-
1891, and it was voted to adhere to the
est already existing. It was also stated in

not be used by the consumer, with a view to
sound opinion on the constancy of volume.
lts of a number of experiments are also given
cussion, showing that a number of cements
not withstood the *kiln* test were sound when
water at normal temperatures, or if placed
being kept moist for several days. It may
ed also that most of the discussion seemed to
y to the dry-heat test.
the leading German cement experts, however,
dvocates of the use of heat tests. Dr. Michaelis
his approval of them, and stated that he had
ed with and used them satisfactorily for a
years at the Charlottenburg experiment
r. Erdmenger also declares that experience
the high-pressure-steam test to give an accurate
on of the permanence of volume of the material.
that most of the best German cements have
test up to a pressure of forty atmospheres for
rs and several for neat cement, the best of them
defect whatever; and he thinks there is no
the statement that many good cements will
test.
uschinger found that cements which had
results in the ordinary 28-day test, and also
cold-pat test for a year, failed when formed
of 1 to 3 mortar for testing in the Bauschinger
aratus. Expansion was detected in six months

...e continuance of the present practice ... for quick determinations and the 28-day ...s decisive), but they state that "the boiling ...oubtedly be considered as the most con-...oid test for the determination of constancy ...*Portland cement, of slag cement, and of* ...fer a particular test to the sub-committee ...mination and report.

... Commission upon Methods of Testing† ...e use of the boiling test as the best method ...a quick determination of the permanence ...Portland cement, the amount of the increase ...be measured directly, instead of simply ...effect upon a small pat.

...*the steam and hot-water test* has been ... Mr. Faija, using a low temperature; ...United States the same test is employed ...ations of the New York Department of ...mperature near boiling. In some instances ...t has also been used in the United States ...ers in the study of their product with very ...

...ility of adopting some form of accelerated

...*of the Conventions held at Munich, Dresden,* ...na, for the purpose of adopting uniform methods ...rials, by J. Bauschinger; translated by O. M. ...Gieseler (*Washington, 1896*).

...des Méthodes d'Essai des Matériaux de Construc-...Paris, 1894 and 1895).

g the matter, the results of which differ
each other as to involve the question in
. Most of these experiments have been
ing the action of heat upon the various
which unsoundness is usually attributed,
om the results whether the hot test gives
ication of the presence of these ingredients
The most common method has been to
antity of quicklime with a good Portland
en observe the action of the test upon the
involves the assumption that certain
ree lime are sufficient to render the cement
results of tests made in this manner are
much variation, due to the nature of
rapidity of action, and the quantity of
may have been originally present in it.
ments have been of much value in show-
of the accelerated tests upon various sub-
discovering the reasons for many of the
radictory results with them. The question
adoption of tests of this character must,
etermined by a comparison of the results
ir use upon the material as found in market
n of the same material in practical use.
periments are desirable which shall system-
re the results of accelerated test upon
nts with the results of tests under normal

tates at the laboratory of the College of Civil Engineering . Cornell University.

A careful study of the available results of experiment eems to justify the following statements:

1. Small percentages of uncombined lime or magnesia the cement are commonly detected by the use of the eat tests, and the same ingredients in sufficient quantity nder the cement unsound in ordinary use.

2. Cement liable to change of volume when employed nder normal conditions is almost invariably detected hen submitted to the hot-water test. There seems to e no well-authenticated instance of failure to condemn ally defective material.

3. Nearly, if not quite, all of the best brands of Portnd cement, and many of natural cement, as found in arket, readily meet the requirements of these tests, hich therefore do not impose so severe limitations pon the choice of cement as is commonly supposed. ith natural cement the results of these tests vary someat with the character of the cement, and the same sts do not seem to be universally applicable. This, owever, is a matter which can only be determined by reful experiment upon each of the various classes of tural cement. Many of them bear the severe tests lly as well as the Portland.

---

* Methoden und Resultate der Prüfung hydraulischen Bindettel (Zurich, 1893).

mal temperatures in fresh water. These
he most part seem to fail if kept in dry air
ted to the action of sea-water. Apparently,
unsoundness may exist which is sufficient
change of volume to take place in a short
vater or in a longer time in dry air, while in
he action of the expansives takes place
y to the mortar. This is shown by the fact
mortar which had failed in the boiling test
of mixing, after being kept several months
er, and then subjected to the boiling test,
o stand the test perfectly, showing that the
e expansives must meanwhile have taken
everal instances pats of cement acting in this
found to blow in dry air.

undness of cement condemned by the heat
he mortar is to be kept submerged in fresh
refore, in many instances at least, question-
e large series of tests made by Prof. Tet-
f 139 samples of Portland cement 17 failed
g test, all of which also failed in a long time
while only 2 were defective in long time in
ater. In the tests made by the author, the
f failures to total number of samples is less
ch, 5 in 53, and 3 of the 5 samples which were
the hot test were later disintegrated when
fresh water.

eness of the cement has an important bear-

...rated without injury to the mortar; but if ...aterial be sifted out, and only the coarse par...oyed in the test, the slower action in the larger ...ay cause distortion and cracking to take ...ether the same difference usually follows in ... has not been satisfactorily determined.

...nd cement which contains free lime in suffi...tity to cause it to swell in the hot test may ...be made to pass that test by adding a small ...f sulphate of lime. The action of this salt ...etting of cement has already been discussed ... The rules of the Association of German ...akers permit the addition of a small propor...hate of lime for the purpose of regulating the ...ting, and conclude that no injury is thereby ...he cement.

...on of the sulphate of lime to correct the expan... of free lime is but imperfectly known. The ... causes cement containing free lime to pass ...ts is well known, but whether the corrective ...tends to the action of the expansives when the ... used under normal conditions has not as ...tisfactorily determined.

...ngest objection that has been urged against ... hot tests is that they fail to detect free lime ...sence of the calcium sulphate. The justice ...ection can only be decided by experiments ...over considerable periods of time to deter...her the material so passed is sound under

experimental stage, and further experiment is
to determine more fully the connection be-
results of tests and the action of the cement

present conditions it may be said that the
on is fairly against the soundness of a cement
pass the hot-water test and in favor of that
ceeds in passing it; but variations in the
l in the conditions under which it is employed
the results, and they cannot be relied upon
inty for all material. Upon ordinary work
in fresh water there is probably no consider-
r of unsoundness in the use of any good brand
although failure sometimes occurs; but for
mportant works, and particularly those to be
to the action of sea-water, it is reasonable to
n tests as are likely to insure good material,
e risk of excluding other good material.

Art. 61. Air-slaking.

es fresh cement, when first opened after being
ill, if tested at once, show an abnormally rapid
tting, and subsequently harden very slowly,
short-time tests very low tensile strength may
If, however, this cement be exposed to the air
lays, it may resume its natural rate of setting,

ety of air-slaking in testing cement is
y some engineers, upon the ground that
be used in the work will not be treated in
nner. In England it is customary to give
to all cement to be used upon important
east ten days, but in the United States the
mmonly used just as received from the
.

l practice seems to favor air-slaking in
probably a cement capable of regaining
ondition in a few days' exposure will not
work, even if used at once, but it would
better in using such cement to air-slake
fore using. It may be remarked, however,
ing does not ordinarily seem necessary.
commonly placed upon the market by the
does not need it. While it may be allowable
aterial the benefit of the operation, probably
of rejection would occur on account of its

nstances the effect of air-slaking a cement
disappears with time; that is, the strength
r after three or six months may be as great
d before as for that mixed after air-slaking,
difference of strength on a test extending
ays is very considerable. This would indi-
ssity of air-slaking the whole of the material
gth is to be developed in the work, although

te a degree of unsoundness likely to be
though this also disappear in the second

on is simply as to the quantity of the ex-
ch may be present without danger to the
n it is used.

CHAPTER VIII.

SPECIAL TESTS.

ART. 62. TESTS OF ADHESIVE STRENGTH.

THE ability of cement mortar to firmly adhere to a
rface with which it may be placed in contact is one
its most valuable properties and quite as important
the development of cohesive strength. Tests for ad-
sive strength are not commonly employed as a measure
the quality of the material, because of the uncertain
aracter of the test and the difficulty of so conducting
as to make it a reliable indication of value. The
hesive properties of the cement are to a certain extent
led into play in the tensile tests of sand mortar, and
ay be inferred from a comparison of neat and sand tests.

Adhesive strength is developed more slowly than that
cohesion. The difference between the two, which is
ually considerable during the early period of hardening,
gradually lessened with time. This is illustrated in
e greater time required for sand mortar than for neat
nent to harden.

Experiments upon the adhesion of mortars to various
bstances are sometimes made, both for the purpose
comparing various cements or methods of use, and to
udy the relative effects of various kinds of surfaces.

tar of the ordinary form for tensile speci-
ne other half a block of stone, glass, or other
be used, of the same section as the mould
, and arranged to be held by a special clip
-machine at the other.

ny and Switzerland the apparatus shown in
employed. The testpiece is shown at *a*;

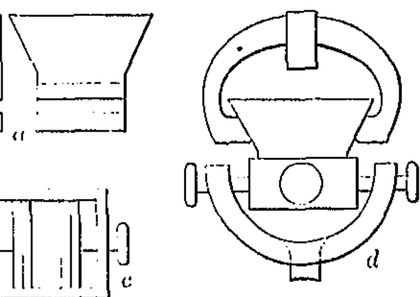


Fig. 28.

ction of 10 square centimeters—twice that
lard tensile specimen. The mortar end is
a wedge shape to catch the upper clip of
machine, while the other end is formed of
ped of marble or ground glass for standard
a cylindrical groove cut in its side, which
pecial clamp (shown at *c*). This clamp is
ws, in the lower clip of the testing-machine,
at *d*. For forming the briquettes moulds

lard tests in comparing different materials; amount of labor involved in the prepara- locks, and the difficulty of getting always ace, has been a bar to the extension of this ound glass has been *more commonly* em- same blocks being repeatedly used. Dr. also used for this purpose standard blocks ortar, of the same form, which are easily more uniform in material and surface.

an Conference on Methods of Testing, oned, did not define a standard test, but matter to a sub-committee, with the recom- at the German apparatus just described

h commission recommend the use of a double T form, suggested by M. Candlot. n Fig. 29. A mould is employed, made to half the briquette, which is set down over be used in forming the specimen.

mendations of the commission are as follows: mpare the adhesive strengths of cements, itted to the tension test a briquette of the m, shown above, each of the materials to nstituting half of one of the specimens.

rd tests, intended to compare the adhesive various cements to the same material.

standard adhesion-blocks are prepared of osed of one part, by weight, of artificial ent, passed through the sieve of 900 meshes

ck. The adhesion-blocks are immersed in
fter twenty-four hours, and kept thus until

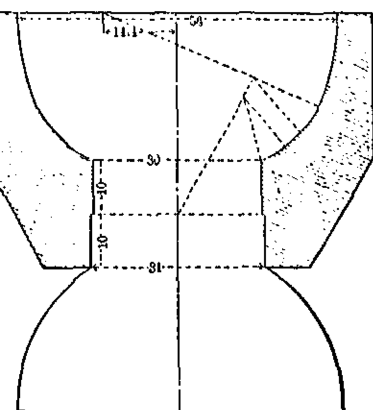


FIG. 29.

east for twenty-eight days. When they are
l, they are dried and the surface is smoothed
paper.

standard plastic mortar (see Art. 44) is
r these tests, introduced by the pressure
el into the moulds, placed in such manner
ndard adhesion-block forms the base. The
removed from the mould when completely

briquettes are tested in the same manner
same periods prescribed for tensile tests."

l can be moulded, the block may be made
vay as the standard block. If the material
te several millimeters thick may be formed
ice dressed. This is placed in the bottom
and the block filled out with neat cement."

ART. 63. CHEMICAL ANALYSIS.

nalysis is of very great value in the study
rties of various cements, and is commonly
manufacturers in regulating the quality of
s. It is not commonly used for the purpose
ng the quality of a cement, and is not of
as a test for the reception of material.
ty of the cement depends not only upon
nts being properly proportioned, but also
e of combination of the ingredients, and this
nds upon the manipulation given the mate-
ıfacture. Analysis shows the proportions of
ingredients, but does not show their state of
. The results of an analysis may show
position is such that a good cement may be
the ingredients, but other tests are necessary
ether it has been made. Chemical analysis
er, prove a cement to be bad through its
bjectionable proportions of ingredients known

annot be detected by analysis, as their necessarily dependent upon the propor- e or magnesia present.

specifications, devised by M. Guillain, ment reject those containing more than acid, or sulphides in appreciable quan- e containing more than 4% of oxide of give less than 44/100 for the ratio of the ghts of silica and alumina to the weight to be regarded with suspicion.

entage of volatile elements in a cement nsufficient burning or deterioration with osure to the air.

states that a chemical analysis may be ng the adulteration of cement, sometimes urope. Upon sifting the cement and yzing the coarse and fine portions an ement should show practically identical wo analyses. He also states that blast- ich is a common adulteration in Portland ometimes be discovered by the odor of drogen upon treating it with hydrochloric

tandard Specifications for Portland Cem- 1904 recommend the following as a re- chemical composition: "There shall be ne, that is to say, the proportion of lime eater than is necessary to saturate silica

Cement of the American Society for Testing in 1904 recommend the following require- Portland cement: "The cement shall not con- than 1.75 per cent of anhydrous sulphuric), nor more than 4 per cent of magnesia

of Analysis.—The following method for the f cement was recommended by committee on in the Analysis of Materials for the Portland ndustry, of New York Section of the Society cal Industry.*

l suggested by Clifford Richardson, for the of Limestone, Raw Mixture, and Portland proposed for trial by the committee and modi- cordance with the suggestions of W. F. Hille-

on.—One half gramme of the finely powdered is to be weighed out, and, if a limestone or mixture, strongly ignited in a platinum crucible blast for fifteen minutes. It is then trans- an evaporating-dish, preferably of platinum, ke of celerity in evaporation, covered with a ss and 10 cc. of HCl, diluted with about 50 cc. added. Digestion on the water-bath is allowed or about 15 minutes, when the substance should

---

nal, Society for Chemical Industry, Jan. 15, 1902.

st with 5–10 cc. of strong HCl, and then with
ter as the dish will comfortably hold. The
n replaced and digestion allowed to go on
tes on the bath, after which the solution is
the separated silica washed thoroughly with
The filtrate is again evaporated to dry-
esidue, without further heating, taken up
nd water and the small amount of silica it
arated on another filter-paper. The papers
ne residue are transferred wet to a weighed
ucible, dried, ignited, first over a Bunsen
bon of the filter is completely consumed, and
the blast for 30 minutes and checked by
asting of 10 minutes or to constant weight.
f great accuracy is desired, is treated in the
h about 10 cc. of HF and four drops of
evaporated over a low flame to complete
ne small residue is washed, finally blasted,
weighed. The difference between this
the weight previously obtained gives the
lica.†

nd Fe_2O_3.—The filtrate about 250 cc., from
evaporation for SiO_2, is made alkaline with

ng remains undecomposed it should be separated,
little Na_2CO_3, dissolved, and added to the original

ary control work in the plant laboratory this cor-
perhaps, be neglected; the double evaporation never.

by decantation and slightly on the filter. Setting the filtrate, the precipitate is dissolved in hot dilute the solution passing into the beaker in which the itation was made. The aluminium and iron are eprecipitated by NH_4OH. The second precipitate ected and washed on the same filter used in the first ce. The filter-paper, with the precipitate, is then l in a weighed platinum crucible, the paper burned d the precipitate ignited and finally blasted 10 es, with care to prevent reduction, cooled and ed as Al_2O_3 and Fe_2O_3.*

Fe_2O_3.—The combined iron and aluminium oxides are in a platinum crucible at a very low temperature about 10 grammes of $KHSO_4$, the melt taken up hot water and 25 cc. of dilute H_2SO_4. The clear on is then digested on the steam bath for about nutes, and, if accuracy is desired, the small amount ca is filtered out, weighed, and corrected by HF H_2SO_4. The filtrate is reduced by hydrogen sul- boiling out the excess afterwards whilst passing hrough the flask, and titrated with permanganate.†

MnO.—To the combined filtrate from the Al_2O_3 and precipitate a few drops of HN_4OH are added and lution brought to boiling. To the boiling solution of a saturated solution of ammonium oxalate are

---

* This precipitate contains TiO_2, P_2O_5, MnO.

† In this way only is the influence of titanium to be avoided, correct result obtained for iron.

laced wet in a platinum crucible, and the paper
f over a small flame of a Bunsen burner. It is
ed, redissolved in HCl, and the solution made
out 100 cc. with water. Ammonia is added in
ess and the liquid is boiled. The small amount
which is separated is filtered out, weighed, and
nt added to that found in the first determination,
at accuracy is desired. The lime is then repre-
by ammonium oxalate, allowed to stand until
ashed, weighed * as oxide by ignition and blast-
nstant weight, or determined with standard per-
te.†

—The combined filtrates from the calcium pre-
are acidified with HCl, and concentrated on the
h to about 150 cc., 30 cc. of $Na(NH_4)HPO_4$
l, and the solution transferred to a beaker and
r several minutes. It is then removed from
and cooled by placing the beaker in ice-water.
ling, NH_4OH is added drop by drop, with con-
ring until the crystalline ammonium-magnesium
osphate begins to form, and then in slight excess,
g being continued for several minutes. It is then
for several hours in a cool atmosphere and
The precipitate is redissolved in hot dilute

---

olume of wash-water should not be too large.
ccuracy of this method admits of criticism, but its con-
nd rapidity demand its insertion.

ved to stand for about two hours, when it is filtered
aper or a Gooch crucible, cooled and weighed as
P_2O_7.

K_2O and Na_2O.—For the determination of the alka-
the well-known method of Prof. J. Lawrence Smith
be followed, either with or without the addition of
O_3 with the NH_4Cl.

SO_3.—One gramme of the cement is dissolved in
:. of HCl, filtered and the residue washed thoroughly.*
The solution is made up to 250 cc. in a beaker and
ed. To the boiling solution 10 cc. of a saturated
tion of $BaCl_2$ are added slowly drop by drop from a
tte and the boiling continued until the precipitate is
formed. It is then set aside over night, filtered,
ted and weighed as $BaSO_4$.

Total Sulphur.—One gramme of material is weighed
in a large platinum crucible and fused with Na_2CO_3
a little KNO_3, being careful to avoid contamination
n sulphur in the gases from the source of heat. The
t is treated in the crucible with boiling water and the
id poured into a tall, narrow beaker and more hot
er added until the mass is all dissolved. The solu-
is then filtered. The filtrate contained in a No. 4
ker is to be acidulated with HCl and made up to
ut 250 cc. with distilled water, boiled, the sulphur
cipitated as $BaSO_4$ and allowed to stand over night.

* Evaporation to dryness is unnecessary.

64. TESTS FOR HOMOGENEITY.

various tests have been proposed for
of detecting the adulteration of Portland
se tests are not usually of a nature in-
se in specifications for the reception of
may sometimes be of use in studying the
of various brands of cement or in classi-
ict of doubtful character. The materials
t with as adulterations include powdered
shale, blast-furnace slag, hydraulic lime,
he nature of the tests depends upon that
ation to be discovered.

ic-gravity test is sometimes utilized for
the foreign matter being lighter than
differences, however, are so small that
st is rather an uncertain one.

nination of the loss upon ignition may
esence of foreign matter containing vola-
while chemical analysis, separating the
se parts of the cement and comparing the
netimes resorted to, as stated in Art. 63.

Test.—The use of the microscope for
of determining the character of the sub-
nt in cement has often been proposed.
atelier made a careful study of Portland
xamining sections of underground clinker

city. Attempts have also been made to
character of the cement by studying the
ch the powder is composed under the micro-
Portland cement, it has been observed that
rtion of the cement is composed of grains
rm and metallic lustre, and that the parts
pearance are probably inert. It has also
that the color of the grains seems to bear
to their value in the cement. Further
veal more positive indications of value based
croscopic appearance, but it seems unlikely
hod will be applied to the determination of
tice.

f homogeneity, the employment of an ordi-
ing-glass may perhaps give useful results.
o made a study of the matter and presented
the French Commission upon Methods of
erials, recommends that the material to be
sifted through the sieve of 4900 meshes
entimeter and the portion retained by that
d in the examination, on account of the
observing the grains when mixed with the
powder. It is also suggested that two
sed: the first of a powder of about three
examine the general appearance and uni-
e material; the second of about eight diam-
in detail the various grains. The material
on a black surface to be examined. The

mind that the character of the material ... the
articles is not necessarily the same as in the
tions, or at least the proportions of the various
ts may not be the same.

ret found that pure cement, thoroughly well
gave "grains all of the same appearance, black,
angular, hard, and with a rough fracture.
ith a drop of water they show at first no change
several minutes a sort of halo appears, pro-
the beginning of crystallization of the soluble
ds. These grains color immediately in hydro-
cid to a yellow, but are completely dissolved
culty.

less burned gives grains equally opaque, but
less deep, varying to brown, gray, or green.
derburned rock gives gray or yellow grains,
rush easily under the point of a knife, and are
by acids with the disengagement of carbonic

n instead of material prepared in the labora-
thoroughly homogeneous, the residue obtained
rket grades of cement is used, the appearance
different even if the material be of best quality.
or is less deep and the material appears very
neous. Such cements contain always, with many
black, brown, or green grains, a large number
vitreous material, green, yellow, and white, with-
aining foreign matter."

bright colors, blue, green, violet, red, and
e materials are usually soft and porous."

in black and brilliant grains, with con-
cture, is found in all the specimens, and
n."

bris of flint from the millstones is not easily
ed from certain underburned cement grains;
he gray morsels, hard and opaque. They
the cement grains in not being attacked by
ids."

pearance of grains of slag vary according
ure of the slag. Commonly, the grains are
of a bluish-gray color, and smooth, clean
Sometimes the grains are vitreous and black.
lar slags employed in making slag cements
nd leave few grains. Their débris has the
of colorless glass, or tint of yellow or green,
res easily under the point of a knife."

ers give round grains, usually more clear in
the grains of cement."

n added to cement clinker before grinding may
e white crystalline grains easily seen. They
entified by their hardness and solubility. Plas-
cult to recognize, because it grinds fine and
rystals."

laster has been added to cement, it may some-
detected by separate analyses of the fine and

he mixture of methylene iodide and benzine, ghtly below that of cement and above that separating by its means the cement from tion. It is thus described by Prof. Le

operation is the preparation of a liquid of ty for the separation,—2.95 for example. l the cement sinks to the bottom and the the surface. To prepare the liquid add to e iodide of density 3.1 a small quantity of pping the moment a crystal of aragonite of just remains at the surface. It is well not nixture directly, but to make two mixtures— le lighter, the other a little heavier, than sought; thus obtaining a more progressive l more easily regulated."

aratus consists of a glass tube (Fig. 30) s in diameter, 70 millimeters high, widened at top and terminated at bottom in a point, ice, 1 millimeter in diameter. This orifice the interior a little above the bottom, by a stopper, fastened to a long glass rod, which he top of the tube.

an experiment, the stopper is wet with se is dissolved by the liquid), to prevent vo grammes of cement are introduced, then entimeters of liquid (density 2.95). It is l in a lively manner with a small platinum

at the bottom and the slag at the top. The

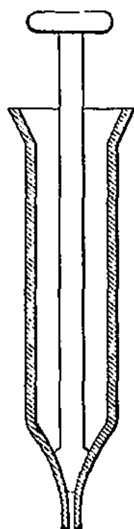


FIG. 30.

emery is lightly raised by the rod to which
d, letting out the cement and part of the liquid,
n replaced. The cement is caught upon a
gh which the liquid passes into a flask, when
for another operation.

ag and remainder of the liquid are received
her filter. Finally the tube and filters are
h benzine and dried; the cement and slag
l, and analyzed chemically if thought proper."

be used for sidewalks, floors, or artificial
times submitted to tests for resistance to
is test is frequently employed in Ger-
pparatus designed by Prof. Bauschinger
This apparatus consists of a cast-iron
timeters in diameter and 3 centimeters
d to rotate horizontally at about 20 revolu-
nute. Specimens 6×6, 10×10, or 12×12
section are employed. They are held
with a pressure of 30 kilogrammes, and
f standard sand are added for each 10 turns.
given, and the loss in weight of the specimen

ws a similar apparatus made by the Riehle
-machine Co., and used for brick and stone
on tests, when employed, are usually made
t cement and sand mortar. The test of
ed in practice is evidently the more impor-
nce to abrasion varies with the character of
nd for sand mortar depends upon the adhe-
ement to the sand and the hardness of the
nd. Sand mortars with moderate propor-
give better resistance to abrasion than neat

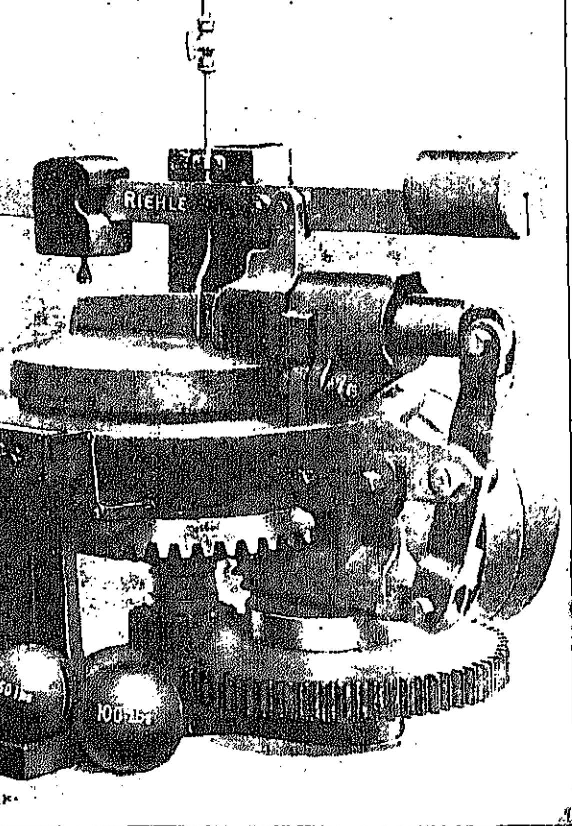


Fig. 31.

properties of the materials and methods
m. The porosity may often be a matter
as affecting the durability of mortar
c action of disintegrating agencies. These
employed for the reception of material.
epends to a much greater extent upon the
ater used in gauging, and the degree of
sed in forming the briquette, than upon
of the cement or sand employed, although
fineness of these materials has some in-

porosity consists in determining the ratio
of voids to the total volume of the mortar.
of determining when the voids are com-
vith liquid, or when the mortar is quite
process a somewhat uncertain one, and
a definite procedure be followed in order
ncordant and comparable results.

usually followed is to measure the total
ne and the volume of material: the volume
n the difference of the two; this divided
me is the percentage of porosity. To
tal apparent volume, the simplest method
block of such form that it may be directly
hen this method is not employed the total
obtained by weighing the block in a satu-
in water and in the air; the difference
o weights is the weight of water displaced,

change during the weighing.

btain the volume of solid material in the block, erence between the weight of the block when air, and of the saturated block in water is ob- This difference is the weight of water displaced l material. To secure good results the entire in the first instance and the complete saturation second is essential. The block may be placed in lry air for a period sufficient to permit the weight ome constant. For this purpose it is necessary e temperature be the same in all cases, as the of hygrometric water given off depends upon perature of drying; 100° to 110° Fahr. has been nes employed, and is recommended by the French ssion on Standard Tests. After the dry weight ined, considerable difficulty may be experienced ng complete saturation. If the block be simply ed, air will be retained in the voids, and a long required to obtain a constant weight. Boiling is nes resorted to, but has the disadvantage of s causing change of volume in the mortar. The ethod of expediting the test is to exhaust the air cing the specimen in water under the receiver of pump.

. Tetmajer recommends* that a temperature of

hoden und Resultate der Prufung der Hydraulischen Binde- Zurich, 1893).

ed by measuring directly the volume of
ed. For this purpose an apparatus is
ch is very similar to the Schuman volu-
ig. 5, but with a removable cover to the
he specimen.

67. TESTS FOR PERMEABILITY.

ability of mortar is quite distinct from
nd the more porous is not necessarily the
le. Tests for permeability, like those for
nteresting and important in the studies of
of mortar, but are not suitable for use
ns for the reception of material. The
for permeability is made by forcing water
ke of mortar under pressure. This may
ed either by subjecting the mortar directly
e of a considerable head of water, or by
block of mortar to a small pressure from
water above, while the air is exhausted,
rtial vacuum below. The latter method
ally preferred in Europe, although the
en made standard in France.

tus shown in Fig. 32 has been frequently
hese tests. It consists of a heavy cylin-
(*a*) with a ground upper edge, upon which
itted the second cylinder (*d*). The speci-
ng a section of 20 square centimeters and

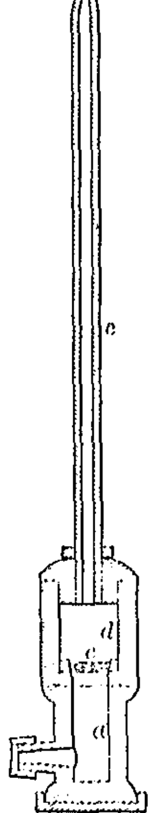


FIG. 32.

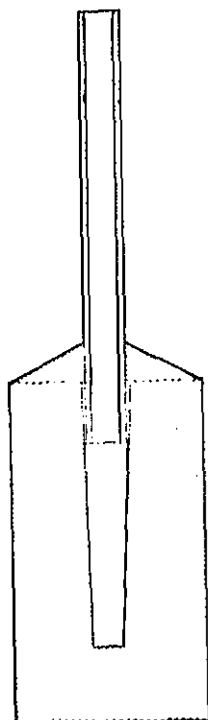


FIG. 33.

A ground-glass stopper covers the cylinder (*b*) arries the graduated tub (*e*), which has a capacity o cubic centimeters and is graduated to 1/2 centi-

cylinder and the cover clamped down, the
ed from *a*, the stop-cock closed, and the
e filled with water to the zero mark. The
ater percolating through the specimen may
from the scale for any desired unit of time.
gement shown in Fig. 33 is also used to
in Europe. It consists of a hollow cylin-

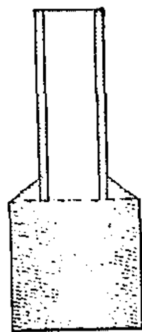


FIG. 34.

110 millimeters in diameter and 200 milli-
of the mortar to be tested, into the top
ass tube is set with neat cement. In making
bber tube is connected with the glass tube
vessel placed at such an elevation as will
ssure desired, which varies according to the
tested.

block, arranged as shown in Fig. 34, is
tly employed. For this purpose the stand-

ssed by the number of liters of water which trans- a cube with faces of 50 square centimeters during en time.

'he water is supplied by a glass tube 35 millimeters ameter and 110 millimeters high, sealed vertically ie aid of neat cement upon the upper face of the . The upper end of the tube is connected by a er tube with a reservoir raised to an elevation cor- nding to the head desired. The heads adopted, ding to the permeability of the mortar, are 0.10 ', 1 meter, and 10 meters.

efore the test is made, the blocks should be im- ed for 48 hours, with such precautions as are neces- to secure as complete saturation as possible. After ning the experiment the block is kept completely ersed.

'he rate of filtration is determined after 24 hours, ys, 28 days, 3 months.

'he determinations are made for three blocks, the results being taken for the two blocks most con- ınt.

'he *standard test* for permeability is to be made upon lard plastic mortar 28 days old, kept under water.

'or tests upon mortars of different ages and com- ions, it is recommended to employ 1 to 2 and 1 mortars made plastic, and 7 days, 28 days, and 3 ths old."

ie permeability of mortars to gases is a matter

frequently made upon cement mortars to
e effect of freezing before setting or while
still comparatively fresh, for the purpose
ng the safety of using the mortar in freez-
or the best method of so using it.
s are usually made by exposing briquettes
temperatures, either by taking advantage
temperatures, or by using a freezing mixture
g the results of tensile tests upon briquettes
th those kept under normal conditions.
is kind may be of much value in showing
properties of various materials, and often
eresting results. They are to be used with
ever, in determining from them the probable
ing upon work in which the mortar may be
ently the results of briquette tests, and the
material in large masses in construction are
nt. Injury to work may perhaps result not
e injurious effect of frost upon the strength
al, but also from expansive action upon the
ar, after setting, while still too weak to offer
stance to distortion.

some laboratories it is the custom to make tests yield of mortar obtained from given weights of aterials employed. This may sometimes be of ance as affecting the economy of use of various als, while a study of the differences obtained with nt material is interesting.

conducting such tests it is evidently necessary to a standard method of gauging the ingredients, the e of the resulting product being much affected by ons in manipulations. The method employed is to measure directly the volume of paste obtained king to standard consistency a unit weight of neat t or of cement and sand in proper proportions. is purpose the paste is put in a graduated glass er, care being taken to eliminate all of the air-es.

etimes the test is made by making blocks of the which are allowed to set, their volumes being uently obtained by greasing their surfaces and the difference of weight in air and water.

Art. 70. Tests of Sand.

ts of the sand to be used in mortar are of much in determining the relative value of different sands as in studying the effect of variations in the nature, or size of grains of which it may be composed.

nplete tests should include an examination of the e of the sand, its fineness as shown by the amount

sted as compared with similar tests made
sand are of most importance as indicating
e sand to combine with cement in forming

CHAPTER IX.

MENT MORTAR AND CONCRETE.

ART. 71. SAND FOR MORTAR.

aulic cement is commonly mixed with cer-
rtions of sand, when used in construction,
and quantity of sand used, and the method
lating the materials in forming the mortar,
as important an effect upon the final strength
k as the quality of cement itself.

ng cement, a standard sand is usually em-
This sand may be obtained quite uniform in
n the execution of work, however, local sand
rally be employed; this varies widely in char-
should always be carefully considered upon
tant work, where the development of strength
g qualities in the mortar are of importance.

portance of the quality of sand in mortar is
nonly appreciated, and but little attention is
ven to securing good sand even when the
subjected to rigid requirements.

wman, in his book on concrete, in speaking
aterials used in concrete, says: "Considering
varied character of sand and gravel, it seems
attention should be given to the particulariza-

e of it from an engineering point of view
different, even in a small area; and to
icular as to the character and quality of
nent, and apparently regardless of that of
l gravel, although the latter form 85% to
volume of concrete at the time of mixing,
able of vindication, especially as Portland-
rete should be a monolithic mass, and the
is to retard induration and decrease strength."

cal nature of the sand does not appear to
portant bearing upon its usefulness in mortar.
d is sometimes thought to exercise a slow
ction, and perhaps aid somewhat in the
ing of the mortar. It is usually the best
purpose. Calcareous sands are good, if not
mposed of soft particles. Argillaceous sand
ss desirable, and has been found in some
parently to cause ultimate disintegration in
although a small admixture of clay in the
ot be objectionable, and has been shown in
res not to decrease the strength when present
not exceeding 10% of the sand.

or use in mortar should be clean, and as
am, mud, or organic matter as possible. In
presence of any foreign matter is to be

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s des Ponts et Chaussées, 1890, vol II. p. 277.

rains.

sand is usually preferable to that which is provided it be fine enough to give a smooth s it gives better strength. The coarse sand ess surface to be coated with cement, and tices are more easily filled. Fine sand re-re water in mixing in order to arrive at the istency, and thus gives usually a more porous Fine sand may, however, be desirable when ious mortar is the object.

e of a mixture of grains of various sizes is esirable, as giving less voids to be filled by nt; and it is frequently found that when the not in considerable excess the strength ob-such a mixture is much greater than is given the large or small grains alone.

doubtless due to the voids in the sand being pletely filled by the cement. Large grains of ize seem desirable where a meagre mortar is ployed, the quantity of cement being insuffi-ill the voids and only used to coat the grains nt them together.

nd is objectionable in mortar exposed to the sea-water on account of the increased porosity. ng quick-setting cement the dryness of the matter of importance; if the sand be damp mixture of sand and cement is made, suffi-isture may be given off to induce hydration

set, was greatly modified in action, prob-
the hydration of the aluminate of lime.
t ten minutes in contact with sand con-
moisture, and then sifted out, had its time
reased from a few minutes to several hours.
nd was very wet, the action was more seri-
s of strength resulted.

r. 72. Proportioning Mortar.

ve proportions of the ingredients to be
ar are usually stated as a ratio of parts of
nd, and the quantities are determined either
volume. Cement should always be meas-
ght on account of the variation in volume
cking, and the difficulty of measuring by
s in the same way, while the sand may con-
neasured by volume.

rtions of sand and cement to be used in
depend upon the nature of the work and
for the development of strength or impervi-
he mortar. The volume of interstices to
es with the forms and sizes of the grains of
e quantity of cement necessary to reach the
n with different sands varies considerably.
of a given weight of sand is also greater when

---

nent et Chaux hydrauliques (Paris, 1891).

portions most commonly used in ordinary
for natural cements, one part cement to one
es two parts sand, and for Portland cement
ement to three parts sand. If the proportions
xture were regulated by the value of the sand
s of economy might frequently require changes
ions, and would usually demand the use of
nd obtainable.

nd in a 1 to 3 mixture frequently gives greater
han a poorer one mixed 1 to 2, and either
y give equally good results in practice.

nent in mortar must, for the best results, both
rains of sand so as to cause them to adhere to
r, and fill the voids between them. Mortar
osed to the action of water, particularly sea-
ould always contain a surplus of cement over
ecessary to fill the voids in the sand.

dlot gives as a minimum for mortar to be
ea-water a proportion of 600 kilogrammes of
a cubic meter of sand, which is to be increased
cement is not finely ground.

nd is to be avoided, if possible; when used,
rtion of cement to be increased.

nplete filling of the voids in the sand so as to
e water from the interior of the mass and pre-
action of the magnesian salts upon the cement
work a matter of first importance.

he mortar is to be subjected to the action of

ing of the lime forms a protection to the
ar, which is not subject, as in sea-water, to
he magnesian salts.

Art. 73. Gauging Mortar.

cement mortar, the cement and sand are
nly mixed dry, the water then added, and
orked to a uniformly plastic condition.
the mortar will depend upon the thorough-
operation; the cement must be uniformly
hrough the sand during the dry mixing,
ghly working the mass after the addition
will greatly increase its strength. In mix-
, by the ordinary method, a platform or
the sand and cement are placed upon the
ayers, with a layer of sand at bottom, and
and mixed with shovels until properly dis-
ugh the mass. The material is then formed
or a mound with a crater at the center, and
necessary added at once, after which the
hrown up from the sides until the water is
and then worked into a plastic condition.
to secure proper manipulation of the ma-
e part of the workmen, it is quite common
at the whole mass shall be turned over a cer-
of times with the shovel, both dry and wet.
ng should be quickly and energetically done,

d until wanted, as the moisture commonly will to some extent act upon the cement.

rge works mechanical mixers are frequently with the advantage of greatly lessening the anipulating the material, and also of insurh mixing.

ntity of water to be used in gauging mortar ermined only by experiment in each instance. upon the nature of the cement and sand, and proportion of sad to cement. The water nsidered as made up of two parts—that necesuge the neat cement to a paste, and that revet the surfaces of the sand. The first varies th the quantity of cement, the second with e sand. Fine sand requires more water than d to reach the same consistency, and mortar d should be made a little more wet than when and, to give the best results in practice. The f water also varies with the dryness of the sand rosity.

ount of water to be used in mixing mortar ry masonry is such that the mortar when nixed shall have a stiff plastic condition. It be a soft, semi-fluid mass. The proper cons described by M. Chandlot as such that if mortar be formed in the hand and allowed to gh a small height, it should neither lose its

ch it is to be in contact.

the proper quantity of water should first by experiment, and afterward, in pre-rtar for use in work, the required quantity time be added by measurement. The ter little by little, or from a hose, should ed.

74. PREPARATION OF CONCRETE.

ny mixture of mortar with coarse material, or broken stone, the office of the mortar together the pieces of the aggregate and between them. In engineering work the crete is commonly formed from hydraulic erm *beton* being also frequently used to aulic concrete.

g concrete by hand the mortar is mixed anner; then the stone is spread over the er of mortar and thoroughly mixed with with shovels. The stone should be re being mixed with the mortar, suffi- its surfaces and prevent the absorption rom the mortar, thus promoting the ad- mortar to the aggregate.

concrete should never, as is frequently ed to a fluid state; not only is the result- f the mortar reduced by so doing, but it perly mixed with the aggregate to form

the work. The consistency of concrete must
ance depend upon its nature and method of
eatest strength may usually be attained by
ewhat dry and heavily ramming, the mortar
ich consistency that the concrete becomes
elly-like, water being brought to the surface
. An extreme either of dryness or wetness
rious.

al mixers are frequently employed for pre-
crete, and are very useful in saving labor
derable quantities are used. There are a
forms which have proven effective in use,
s unnecessary to enter into a discussion of

regate used for concrete should be as hard
e as possible, and that of angular form is
to rounded. Angular forms give a greater
the adherence of the mortar in proportion
while leaving a less volume of interstices to
ith mortar. The materials should be uni-
ality. Where gravel is used which varies in
should be blended by mixing in order to
orm strength in the concrete. Porous aggre-
o be avoided, as they are likely to absorb
. When the materials are absorbent, they
saturated in sprinkling before using, in order
withdrawing water from the mortar before
es place.

...is work under consideration. When the ...ired to be water-tight, the amount of cement ... sufficient to fill the interstices in the mix-...nd sand. The quantity of sand necessary ...stices in the stone may be determined by ...ure with stone as closely as possible, and ...g the quantity of water which can be ...e measure; this gives the volume of sand ...he *proper quantity of damp sand be added* ... the measure by shaking it down so as to ... the volume of water which can then be ...sure is the volume of cement paste necessary ...s in the aggregate.

...h of concrete usually varies nearly in ... the amount of cement used in forming ...strong concrete is desired, it should be ...ncreasing the richness of the mortar in ...y increasing the proportion of mortar to ... above the point at which the sand fills the ...that material. If the proportion of sand ...his, the resulting concrete will be porous ...ughly solidified; if it be greater, the excess ...be an element of weakness in the concrete. ... of concrete in considerable masses the ... the work is sometimes formed of very ...e, with a facing of stronger water-tight ...otect it. This weak concrete is frequently ...mitting the sand altogether and simply ...one lightly with neat cement, causing the

to 5/10 of the volume, depending upon its uni-
ity in size. Where there is considerable variation
ize, the voids may be somewhat less. When the
stices are to be filled, it is desirable that the aggregate
ain material of various sizes, to reduce the volume
nterstices. For this reason small gravel is sometimes
ed with broken stone in the preparation of concrete.
he proportions in common use for concrete of Port-
cement vary from 1 part cement, 2 parts sand,
5 parts broken stone to 1 part cement, 4 parts sand,
8 or 10 parts broken stone or gravel. Usually the
tar is made richer when natural cement is used.
proportions of course vary with the character of the
erials to be used as well as that of the work to be done,
can only be properly determined by the exercise of
d judgment, in the light of experience.

ART. 75. YIELD OF MORTAR AND CONCRETE.

The volume of mortar formed by mixing given quan-
es of cement and sand depends upon the densities of
materials and the volume of interstices in the sand.
s affected also by the method of preparing the mortar,
uniformity of the mixing, and the degree of compact-
ss given.

The net volume of materials entering into the compo-
ion of mortar or concrete is readily found from their
ights and densities, but it represents only approximately

nent is usually sold in barrels containing
Natural cements are lighter, and are
els of 260 to 320 lbs. Barrels of Rosen-
sually contain 300 lbs.

of neat cement paste made by a given
nt powder varies with the specific gravity
and the amount of water necessary in
lighter cements require more water and
for a given volume of cement than the
To form a cubic foot of plastic paste
y from 75 to 90 lbs. of natural-cement
80 to 85 lbs. of Rosendale cement being
about 95 to 100 lbs. of Portland cement

nd mortar, where the cement and sand
d by volume measured loose, the quantities
n a cubic yard of mortar are approximately

	Natural Cement. Pounds.	Portland Cement. Pounds.	Sand. Cu. Yd.
..	1050 to 1250	1350 to 1530	.65 to .70
...	640 " 720	810 " 920	.80 " .85
...	500 " 575	620 " 690	.93 " .96
...	400 " 460	500 " 575	1.00
...	320 " 375	400 " 460	1.00

e, when the aggregate is broken stone
e, it is necessary, in order to fill the in-
mortar, that the volume of morter be 50%
of the aggregate. For such concrete a
ut .9 cubic yard of broken stone with .50

cement, 3 parts sand, and 5 parts broken stone.

here the stone is more irregular in size, or if gravel
naller size be added, a smaller proportion of mortar
give good results. Thus, .9 cubic yard of broken
with .4 cubic yard of gravel and .3 cubic yard of
ar has been found to yield 1 cubic yard of good
rete. This, using 1 to 2 mortar, gives the propor-
1 part cement, 2 parts sand, 3 parts gravel, and 7 parts
en stone.

hen the amount of mortar used is less than that
ated above, and the interstices in the aggregate
not filled, the yield of concrete is about equal to the
me of aggregate employed.

Art. 76. Mixtures of Lime and Cement.

aked lime is sometimes mixed with hydraulic cement
the purpose of decreasing the cost of construction.
eriments seem to indicate that a very considerable
entage of lime may frequently be added without mate-
loss of strength in the mortar.

Vith Portland cement the addition of lime weakens
mortar somewhat, the decrease in strength aug-
nting rapidly as the proportion of lime increases.

Vith some American natural cements it has been
nd that a certain amount (sometimes 30% to 40%) of
e may be added without sensibly decreasing the
ngth of the mortar or impairing its hydraulic prop-

mortar by the admixture of lime, better
ained than by using a higher proportion
ortar thus formed is less porous than that
ger proportion of sand, and it is also more
er to work. In making the mixture the
y slaked in the usual manner and used
aste, although it may be slaked to powder
ith the cement. By the first method the
of the lime is insured.

e of lime causes the cement to become
he quick-setting cement being affected
an the less active ones.

small proportion of Portland cement is
d to hydraulic lime for the purpose of
setting and increasing the strength of

natural and Portland cement have fre-
ed in the United States for the purpose
e action of the quick-setting material or
construction. They seem generally to
ounded of those which would be obtained
gly.

of all these mixtures will be found to
particular cement employed, and the
be known by trial in each instance. In
good results, the mixtures must be very

ot injured by freezing, when frozen before
he cement sets with extreme slowness, if at all
but after thawing it sets and hardens properly.
en for short periods—a few days—does not
ozen, but the experiments of Mr. Cecil B.
cGill University seem to show that if kept
sufficient period it may finally set while frozen.
ening of cement which has been frozen is
slow than that unfrozen, but it may ulti-
the same strength.

constructed during freezing weather is fre-
ured by freezing, notwithstanding the fact
nent itself shows no loss of strength due to
The effect of frost coming upon the work
fully hardened is frequently to distort or
ual settlement in it, and sometimes repeated
l thawing gradually cause the mortar to be
of place or perhaps to become cracked and
d on the outside. The construction of cement
uring freezing weather is therefore usually
s hazardous, unless some means be adopted
ng the freezing action. Many instances may,
e cited where extreme cold has not injured
ucted, without such precaution, with Portland
tar, and it is claimed by many engineers that
ay be used with impunity in freezing weather,
it is not placed in work while a freezing
e prevails. It is commonly agreed that most

ng been injured by changing temperature
er, although it may not have frozen for
e after setting.

ommonly used in cold weather to prevent
ortar while it is soft. A strong solution,
urated one, is employed. The salt, by
eezing of the water, prevents any distorting
ion upon the work due to the change in
mortar. The use of salt considerably
tivity of the cement, and mortar may
condition at freezing temperatures and
the temperature becomes sufficient to

early strength of cement mortar which
with salt water on exposure to low tem-
setting is usually greater than that of
e salt and exposed at the same tempera-

salt upon the strength of various kinds
e different. In nearly all, the strength
in air is increased by its use. When
ept under water, most cements have
ly strength from the use of salt, which
final strength being somewhat reduced.
most Portland cements. Some natural
material loss of strength when mixed
while others are entirely ruined by a
with or without the use of salt. Care
taken to determine the action of salt

contact with water immediately after setting, as times salt mortar which has been exposed to low erature may lose its cohesion if submerged soon setting.

la has sometimes been employed to prevent the ng of mortar, but its use has not become exten and has usually proven unsatisfactory.

t water should not be used in mixing mortar in ng weather. It not only decreases the strength e mortar, but renders it more liable to injury from Heating the stones or bricks in the construc- of masonry in freezing weather may be beneficial, rving to accelerate the setting and keep the mor- om freezing while soft.

e injury done to the mortar by low temperatures is ably not usually due to freezing before setting, but ernate thawing and freezing while work is still fresh, e hardening is sufficiently advanced to render the ar capable of adequately resisting the expansive s. The effect of frost upon mortar which has set nilar to that upon stone or brick, and is due to the ase in volume of water freezing in its pores. Its therefore depends both upon the porosity of the ar and upon the strength it possesses to resist dis- on. The more rapid acquisition of strength by and cements may give them the advantage they ss in this regard.

of. Le Chatelier, from his experiments upon the er, concludes as follows: "This disintegration, like

ate void are small. When the voids are
ge, the ice breaks with a pressure less
ich will rupture the mortar. *For this*
of large sand are less affected, the voids
d less numerous."

ROSITY AND PERMEABILITY OF MORTAR.

of cement mortar depends rather upon
on of the materials in gauging than upon
he cement. When the quantity of cement
to fill the voids in the sand, spaces are
mit the absorption of water without in-
lume of the mortar.

mortar air-bubbles attach themselves to
the number of which is greater as the
ed more wet. Working the mortar tends
em. Voids in the mortar are also caused
ation of surplus water used in mixing.
ater as the quantity of water used in gaug-
l and as the sand used is finer.

bility of cement mortars varies with the
cement and the circumstances of its use.
t Portland cement may be made practi-
able under a considerable head of water;
of cement and sand seems always more
ble, but when properly proportioned and
lly permits very little water to pass.

ability of mortar decreases rapidly with

blocks of mortar be submitted to the continuous
tion of water, the permeability diminishes very
lly, and after a few months all mortars, except
of very coarse sand and feeble proportion of
nt, become practically impermeable.

oth the porosity and permeability are less for
ar rich in cement than for that in which the pro-
ion of cement is small. Mortar mixed dry is pene-
d more readily than that mixed to a plastic or semi-
condition. With the lapse of time, however, the
ar mixed dry, if constantly exposed to water, ap-
ches the others in resistance to permeation. The
oughness of mixing and degree of compacting em-
ed are more important factors than the absolute
ntity of water used in mixing.

ine sand, according to the experiments of M. Alex-
re, renders the mortar more porous and less per-
ble than coarse sand. When the sand is of varying
s both the porosity and permeability may be low.
any case, to attain a reasonable resistance to pene-
ion, it is necessary that the interstices in the sand
entirely filled with cement. Cleanliness of the sand,
freedom from all foreign material, is of first impor-
ce in the preparation of impermeable mortar.

Masonry of ordinary brick or stone can only be made
pervious by the application of a coating of some
d to its face. A plastering of neat cement or rich
rtar may sometimes be used for this purpose, and

e, as with masonry, to coat the face of
n order that concrete may be reasonably
necessary that the quantity of cement
reparing it be sufficient to fill the voids in
al employed, as well as that the voids in
pletely filled with cement paste in mak-

NSION AND CONTRACTION OF MORTAR.

large masses of masonry or concrete
s liable to occur in the volume of mortar
become of importance, and it may be
ke provision by which changes in dimen-
ace without injury to the work.

t of expansion for neat cement under
eat is, as previously stated, about the
n, although it may vary in individual
mortars containing sand, the coefficient
eat cement.

r considerably in their behavior during
of the hardening process, as to the
es place in the volume of the mortar.
t is apt to swell and become distorted
ement of the process of disintegration,
any considerable change of this nature
obable destruction of the mortar. Per-
nent, although not altered in form, is
somewhat in dimensions during hard-

sachusetts Institute of Technology for a committee of the American Society of Civil Engineers, found that for small blocks of mortar the change was the same in all directions; that for neat cements the linear contraction in air varied from 0.14% to 0.32% for the first twelve weeks after mixing, and the linear expansion in water varied from 0.04% to 0.25%. When sand was used the change was less, giving a contraction in air from 0.08% to 0.17%, and an expansion in water of from 0.00% to 0.08%.

The rapidity of the change varies somewhat with the activity of the cement; the conclusion being that a quick-setting cement changes more in volume than a slow-setting one.

Further experiment is desirable, that the action of the various classes of cement may be better understood.

Art. 80. Effect of Retempering Mortar.

Masons frequently mix mortar in considerable quantities, and, if the mass becomes stiffened before being used by the setting of the cement, add more water and work again to a soft or plastic condition. After the second tempering the cement is much less active than at first, and remains a longer time in a workable condition.

This practice is not usually approved by engineers, and is not permitted in good engineering construction, although there is some dispute as to its injurious effect.

lar plastic at the second working. The
mortar so treated is very slow at first, but
ently (the tests extend over three years)
strength as when gauged immediately

equently claimed that the *adhesive prop-*
r are improved by giving it the "second
nmon practice of masons who set fire-
d similar work is based upon this idea.
ment to determine this point would be

of experiments other than those already
eemed to show that in some instances
to mortar by retempering, some cements
to set the second time. Until more is
action of the material when subjected to
it seems advisable to mix only such
ce as may be used before the initial set
and to reject any material that may have
g placed in the work.

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des Ponts et Chaussées, 1888, vol. I. p. 375.

APPENDIX.

TIONS FOR THE RECEPTION OF CEMENT.

GENERAL REMARKS.

ssion which has been given of the various cement, the requirements of specifications nsidered, but it is thought desirable to actual specifications to show the require-l in practice.

ations recommended by the committee of Society of Testing Materials for use by neers are first given. These specifications ered as the standard of the best American sent, although many specifications in com- in important particulars from them.

ifications of existing practice at the time on are recommended by these specifications, od of testing soundness and in the use of e for rate of setting.

Standard Specifications recommended by ing Standards Committee" in 1905 are also

a few brands, or of a single brand, employ
ations, but depend upon the reliability of
or perhaps upon occasional examinations
at the material is up to standard. This is
the practice upon ordinary railroad work,
e instances, where the use is continuous and
tracts may be made for the material, is quite
.

eems, generally, to be no good reason for
ecifications in an indefinite manner. The
to be imposed may as easily be plainly stated,
ave no doubt as to the requirements.

A.

RICAN SOCIETY FOR TESTING
MATERIALS.

RT OF COMMITTEE ON STANDARD
SPECIFICATIONS FOR CEMENT.

GENERAL OBSERVATIONS.

e remarks have been prepared with a view of
ut the pertinent features of the various require-
the precautions to be observed in the interpre-
he results of the tests.

committee would suggest that the acceptance or
under these specifications be based on tests
n experienced person having the proper means
g the tests.

th the results of other tests may afford
tions.

–The sieves should be kept thoroughly dry.

tting.—Great care should be exercised to
st pieces under as uniform conditions as
dden change or wide range of temperature
which the tests are made, a very dry or
ere, and other irregularities vitally affect
ng.

rength.—Each consumer must fix the
irements for tensile strength to suit his
. They shall, however, be within the

of volume.—The tests for constancy of
ided into two classes, the first normal, the
ated. The latter should be regarded as
test only, and not infallible. So many
into the making and interpreting of it that
ed with *extreme care.*

g the pats the greatest care should be
oid initial strains due to moulding or to
ng out during the first twenty-four hours.
ld be preserved under the most uniform
sible, and rapid changes of temperature
ded.

e to meet the requirements of the accele-
not be sufficient cause for rejection. The
owever, be held for twenty-eight days and

nsoundness, nor can the cement be considered isfactory simply because it passes the tests.

ANDARD SPECIFICATIONS FOR CEMENT.

al conditions.—All cement shall be inspected.

nt may be inspected either at the place of re or on the work.

ler to allow ample time for inspecting and testing should be stored in a suitable weather-tight aving the floor properly blocked or raised from l.

cement shall be stored in such a manner as to y access for proper inspection and identification ipment.

facility shall be provided by the contractor od of at least twelve days allowed for the inspec- ecessary tests.

ent shall be delivered in suitable packages rand and name of manufacturer plainly marked

g of cement shall contain 94 lbs. of cement net. rel of Portland cement shall contain 4 bags, barrel of natural cement shall contain 3 bags, ove net weight.

ent failing to meet the seven-day requirements eld awaiting the results of the twenty-eight-day re rejection.

e Society Jan. 21, 1903, and amended
vith all subsequent amendments thereto.
ptance or rejection shall be based on the
ements:

NATURAL CEMENT.

n.—This term shall be applied to the
d product resulting from the calcination
ous limestone at a temperature only suffi-
ff the carbonic-acid gas.

Gravity.—The specific gravity of the cement
d at 100° C. shall be not less than 2.8.

—It shall leave by weight a residue of
10 per cent on the No. 100 and 30 per cent
sieve.

Setting.—It shall develop initial set in not
inutes, and hard set in not less than thirty
nore than three hours.

Strength.—The minimum requirements for
n for briquettes 1 inch square in cross-
be within the following limits, and shall
ogression in strength within the periods

NEAT CEMENT.

	Strength.
oist air.	50–100 lbs.
in moist air, 6 days in water) .	100–200 "
" " " 27 " " ")	200–300 "

ancy of volume.—Pats of neat cement about
liameter, ½ inch thick at center, tapering to a
all be kept in moist air for a period of twenty-

. pat is then kept in air at normal temperature.
nother is kept in water maintained as near
70° F. as practicable.
: pats are observed at intervals for at least
days, and, to satisfactorily pass the tests,
ain firm and hard and show no signs of dis-
cking, cracking, or disintegrating.

PORTLAND CEMENT.

ition.—This term is applied to the finely
product resulting from the calcination to
usion of an intimate mixture of properly
d argillaceous and calcareous materials, and
addition greater than 3 per cent has been made
to calcination.
fic gravity.—The specific gravity of the cement,
dried at 100° C., shall be not less than 3.10.
ess.—It shall leave by weight a residue of not
8 per cent on the No. 100, and not more than
: on the No. 200 sieve.
of setting.—It shall develop initial set in not
hirty minutes, but must develop hard set in
n one hour, nor more than ten hours.

strength within the periods specified:

NEAT CEMENT.

	Strength.
ist air.	150-200 lbs.
in air, 6 days in water).	450-550 "
" " 27 " " "	550-650 "

PART CEMENT, 3 PARTS SAND.

in moist air, 6 days in water).	150-200 lbs.
" " " 27 " " ").	200-300 "

ty of volume.—Pats of neat cement about diameter, one half inch thick at the centre, to a thin edge, shall be kept in moist air twenty-four hours.

then kept in air at normal temperature and tervals for at least 28 days.

pat is kept in water maintained as near practicable, and observed at intervals for s.

pat is exposed in any convenient way in of steam, above boiling water, in a loosely or five hours.

pats to satisfactorily pass the requirements irm and hard and show no signs of distor- , cracking, or disintegration.

ic acid and magnesia.—The cement shall nore than 1.75 per cent of anhydrous sul- SO_3), nor more than 4 per cent of mag-

TIONS ISSUED BY THE ENGI-
G STANDARDS COMMITTEE.

SUPPORTED BY

TUTION OF CIVIL ENGINEERS.
TUTION OF MECHANICAL ENGINEERS.
TUTION OF NAVAL ARCHITECTS.
AND STEEL INSTITUTE.
TUTION OF ELECTRICAL ENGINEERS.

TANDARD SPECIFICATIONS FOR
PORTLAND CEMENT.

preparation.—(1) The cement is to be
timately mixing together calcareous and
aterials, burning them at a clinkering
nd grinding the resulting clinker. No
y material is to be made after burning,
lesired by the manufacturer, and if not
writing by the consumer, in which case
te or water may be used. The cement,
all contain not more than 2 per cent of
that water has been added or has been
rbed from the air. If calcium sulphate
nore than 2 per cent calculated as anhy-
sulphate of the weight of the cement shall

d preparation for testing and analysis.—(2)
e cement has been bulked at the maker's

ne same heap, so distributed as to insure
practicable a fair average sample of the
all to be mixed together and the sample
be taken therefrom.

gauging the tests, the sample so obtained is
out for a depth of 3 inches for twenty-four
nperature of 58° to 64° Fahr.

cases where consignments are of 100 tons
samples selected as above for each con-
her at the maker's works or after delivery
where the cement is to be used, are to be
rt testing and for chemical analysis. In no
nt so tested and analyzed to be accepted or
previously certified in writing by the con-
of satisfactory quality. Payment for such
nalyses to be made by the consumer, the
r supplying the cement required for the
f charge. When consignments of less than
ve to be supplied, the maker shall, if re-
certificates for each delivery, to the effect
ment complies with the terms of this stand-
ation, with regard to quality, tests, and
alyses, no payment being made by the con-
such certificate nor for the making of such
alyses.

d it be deemed more convenient by the con-
the samples for testing should be taken at
s works before delivery, the latter are, in

npled by him. No parcel is to be sent away
tten order has been previously received by
from the said consumer to the effect that
in question has been approved.

ind sieves.—(6) The cement shall be ground
ith the following degrees of fineness, viz.:
ie on a sieve 76×76 = 5776 meshes per square
o exceed 5 per cent.

ue on a sieve 180×180 = 32,400 meshes per
is not to exceed 22½ per cent.

s are to be prepared from standard wire;
he wire for the 5776 mesh is to be .0044 inch
32,400 mesh .0018 inch. The wire shall
ot twilled), the cloth being carefully mounted
nes without distortion.

ravity.—(7) The specific gravity of the cement
less than 3.15 when sampled and hermetically
makers' works, nor less than 3.10 if sampled
y to the consumer.

composition.—(8) The cement is to comply
llowing conditions as to its chemical com-
There shall be no excess of lime, that is to
oportion of lime shall not be greater than is
o saturate the silica and alumina present.
tage of insoluble residue shall not exceed
t; that of magnesia shall not exceed 3 per
hat of sulphuric anhydride shall not exceed
.

form a smooth, easily worked paste
the trowel cleanly in a compact mass.
to be used for gauging, the temperature
the test-room at the time the said opera-
med, being from 58° to 64° Fahr.
gauged as above is to be filled, without
ming, into moulds; each mould resting
ate until the cement has set. When the
sufficiently to enable the mould to be
t injury to the briquette, such removal
l. The said briquettes shall be kept in
here and placed in fresh water twenty-
r gauging and kept there until broken,
hich the test briquettes are submerged
every seven days and the temperature
ned between 58° and 64° Fahr.

10) Briquettes of neat cement are to be
aking at seven and twenty-eight days,
briquettes for each period. The average
of the six briquettes shall be taken as
ensile strength for each period. For
iquette is to be held in strong metal jaws,
being slightly greased where gripped by
load must then be steadily and uniformly
from zero, increasing at the rate of 100
seconds. The briquettes are to bear on
less than the following tensile stresses
:

hen the 7-day test falls between 400 to 450 lbs. re inch.

vhen the 7-day test falls between 450 to 500 lbs. re inch.

vhen the 7-day test falls between 500 to 550 lbs. re inch.

vhen the 7-day test falls between 550 lbs. per ch or upwards.

'ests.—(11) The cement shall also be tested by f briquettes prepared from one part of cement parts by weight of dry standard sand, the said s being of the shape described for the neat-tests; the mode of gauging, filling the moulds, aking the briquettes is also to be similar. The on of water used shall be such that the mixture ughly wetted, and there shall be no superfluous vhen the briquettes are formed. The cement d briquettes are to bear the following tensile

from gauging. . 120 lbs. per square inch of section.
" " . . 225 " " " " " "

ncrease from seven to twenty-eight days shall not than 20 per cent.

standard sand referred to above is to be obtained eighton Buzzard. It must be thoroughly washed, nd pass through a sieve of 20×20 meshes per inch, and must be retained on a sieve of 30×30

' and "slow."*

The setting-time shall not be less than ten more than thirty minutes.

The setting-time shall not be less than half more than two hours.

The setting-time shall not be less than two ore than five hours.*

perature of the air in the test-room at the time and of the water used is to be between 58° hr.

ent shall be considered as "set" when a needle at end $\frac{1}{16}$ inch square, weighing in all $2\frac{1}{2}$ lbs., ake an impression when its point is applied ne surface.

ss.—(13) The cement shall be tested by the er method, and is in no case to show a greater than 12 millimeters after twenty-four hours' nd 6 millimeters after 7 days' aeration.

The apparatus for conducting the Le Chatelier ts of a small split cylinder of spring brass or able metal of 0.5 millimeter (.0197 inch) in 30 millimeters (1.1875 inches) internal diam- 30 millimeters high, *forming the mould to which* side of the split are attached two indicators meters (6.5 inches) long from the cylinder, ted ends.

---

a specially slow-setting cement is required the minimum ing shall be specified.

The mould is then covered with another glass small weight is placed on this, and the mould is ely placed in water at 58° to 64° Fahr. and for twenty-four hours.

stance separating the indicator points is then and the mould placed in cold water, which is o the boiling-point in 15 to 30 minutes and ng for six hours. After cooling, the distance the points is again measured; the difference he two measurements represents the expansion ment, which must not exceed the limits laid this specification.

he tests and analyses hereinbefore referred to o case relate to a larger quantity of cement than sampled at one time.

nce.—(15) No cement is to be approved or unless it fully complies with the foregoing con-

C.

S. RECLAMATION SERVICE, 1905.

F. H. NEWELL, *Chief Engineer.*

inition.—The cement shall be high-grade Portment. By the term Portland cement is to be od the material obtained by finely pulverized produced by burning to semi-fusion an intimate

...rtion of the sum of calcium oxide and
sum of the silica, alumina, and ferric
be less than 1.7 to 1 nor more than 2.2
not contain over 3 per cent of magnesia
of sulphate of lime. But in certain cases
unts of these substances are objectionable
charge may specify lower percentages.
m uncombined lime shall be determined
. The question of adulteration may be
er by chemical analyses or by inspection
t the factory.

ls will be received only from manufacturers
ized agents, and the name of the brand
all cases be stated.

barrel or sack.—The average weight per
be less than 375 lbs. net. Four sacks
barrel of cement. If the weight as deter-
weighings is found to be below 375 lbs.
contractor may be required to supply, free
United States, an additional amount of
the shortage.

amaged cement.—If the cement is delivered
barrels shall be strong and lined with
cement shall be free from lumps. Any
broken or that contains damaged cement
by the United States agent in local charge.

—Samples of cement are to be taken from
acks with a sampling-tube in such manner
ir average of the packages. They are to

arate and tested separately. Where the results ndicate variation in the quality of the cement, l barrels or sacks will be sampled and tested.

ation and testing.—No cement shall be shipped least sixty days after its manufacture, except ase of an emergency, and with the approval of neer in charge, a shorter time may be allowed, ne cement shows indications of unsoundness, a ime may be required. The contractor shall torage, in sacks or barrels, such stocks of cement engineer shall require, free of expense to the States, for sampling and testing during a period y-eight days.

pment.—The engineer shall give notice in writhe contractor of the approximate requirements ent shipments and of dates for sampling. In the contractor shall be responsible for the de-' the cement in good condition at the place of nent.

ctory inspection.—The Government engineer, or norized agent, shall at all times have liberty ct the materials, process of manufacture, and boratory records of analyses and tests at the works.

ineness.—Ninety-five per cent by weight must rough a No. 100 sieve having 10,000 meshes per inch, the wire to be No. 40 Stubbs wire gauge; per cent by weight must pass through a No. 200

be less than 3.

—Pats are to be made of neat mortar tency. The pats are to be moulded on ey are to be circular in shape, 3 inches ch thick in the centre, and drawn to a circumference, and are to be kept under n a moist atmosphere, until finally set. put in water, the temperature of which the boiling-point and kept at that point f the pat softens, cracks, warps, or dis- ment is unsound.

elling.—The cement shall *not* acquire less than *forty-five minutes*, and must set within twelve hours. The pats soundness may be used in determining ng. The cement is considered to have al set when the pat will bear, without indented, a wire $\frac{1}{12}$ inch in diameter one fourth pound. The final set has hen the pat will bear, without being nted, a needle $\frac{1}{24}$ inch in diameter one pound.

riquettes. — In making briquettes, neat normal consistency will be used. The roughly mixed with a trowel and kneaded with the thumbs, a blunt stick, or a quettes will be made from each sample. briquettes, the proportions shall be nt of cement to three parts of standard

above shall stand a minimum tensile strain
nch as follows:

air and 6 days in water............. 450 lbs.
" " 27 " " " .... 550 "

l-mortar briquettes, prepared as specified
stand a minimum tensile strain per square
ws:

n air and 6 days in water........... 175 lbs.
" " " 27 " " " .... 225 "

rements.—The above are to be considered the
equirements. The neat tests are to be con-
less value than those of sand and cement.
-eight-day tests must always be higher than
ay tests. A cement may be rejected which
t any of the above requirements.

D.

ATIONS FOR MUNICIPAL WORK IN
DELPHIA. DEPARTMENT OF PUB-
WORKS.

BUREAU OF SURVEYS.

EORGE S. WEBSTER, *Chief Engineer.*

d weight.—Portland cement only shall be
rels shall contain 376 lbs. net. Bags shall
lbs. net each.

use it. The chief engineer shall be notified
n receipt of each shipment at the work. No
e used unless delivered in suitable packages
nded.

—The cement must be protected in a suita-
having a wooden floor or platform raised
ound, and may be reinspected at any time.

brand.—The failure of a shipment of cement
k to meet the following requirements may
ther use of the same brand on that work.
ment must be immediately removed from

-The acceptance or rejection of a cement to
all rest with the chief engineer, and will be
e following requirements:

ravity. Not less than 3.1.

ensile strength:

ay in air, 6 days in water). . . . . 500 lbs.
" " "27 " " "). . . . . 600 "
ay in air, 6 days in water) 1 part of
3 parts standard quartz sand. . . . . . . 170 lbs.
ay in air, 27 days in water) 1 part of
3 parts standard quartz sand. . . . . . . 240 lbs.

—Residue on No. 100 sieve not over 8 per
ght.

on No. 200 sieve not over 25 per cent by

hall require at least 20 minutes to develop

of volume.— Pats of cement 3 inches in
half inch thick at centre, tapering to thin
ed in water after 24 hours in moist air,
signs of cracking, distortion or disintegra-
r pats in air shall also remain sound and

anhydride (SO_3). Not more than 1.75 per

MgO).—Not more than 4 per cent.
for testing shall be 1 sq. in. area of cross-
es shall be of brass-wire cloth having ap-
,800 and 37,500 meshes per sq. in. respec-
liameter of wire being .0045 and .0023

requirements.—All cements shall meet such
quirements as to chemical and accelerated
chief engineer may determine. The re-
or "set" may be modified where the con-
ch as to make it advisable.

WAUKEE AND ST. PAUL RAIL-
PANY. BRIDGE AND BUILDING
NT.

ONS FOR PORTLAND CEMENT.

CHICAGO, Nov. 28, 1904.

t will be sampled in such a way as to
ge quality of cement in the car. Such
ested in the Company's Laboratory,
n to the Standard Specifications for
adopted by the Committee of the
for Testing Materials in June, 1904,
General Conditions," Paragraphs 1 to
Strength," which will be as specified
ods of testing are those recommended
ports of the Special Committee "On
Cement," of the American Society of
) January, 1904.

, *Fineness, Time of Setting, Constancy*
Amount of Sulphuric Acid and Mag-
with the specifications of the "Ameri-
esting Materials," above referred to.

TENSILE STRENGTH.

requirements for tensile strength for
square in section shall be as follows:
all show no retrogression in strength
specified and the sand tests shall show
least 15% between 7- and 28-day tests.

27). . 600

(one part cement to three parts sand):

day in moist air and 6 days in water). . 175 lbs.
" " " " " 27 " " "). . 250 "

GENERAL CONDITIONS.

shall be uniform in color, free from lumps and
ostances, and shall have been properly aged.
shall be delivered in suitable packages with
and the name of the manufacturer plainly
ereon.
of cement shall contain 94 lbs. cement net.
l of Portland cement shall contain four bags.
ts made by the Railway Company shall be
e Engineer and Superintendent of Bridges
ings reserves the right to reject, on the first
test, any shipment of cement because of failure
ne above requirements, or for any other cause
may deem sufficient.
rejected on account of failure to meet the
uirements will be held subject to the order of
r and at his expense for freight charges to and
point where the cement was to have been used.

J. C. Hain,
Engr. Mas. Const.

:
Loweth,
Engr. and Supt. B. and B.

THE SECOND PARAGRAPH OF "SPECIFICA-
ORTLAND CEMENT" OF THE CHICAGO,
ND ST. PAUL RAILWAY COMPANY, UNDER
. 28, 1904.

SPECIFIC GRAVITY.

vity of the cement, thoroughly dried at
be less than 3.10.

FINENESS.

weight a residue of not more than 8%
nd not more than 45% on the No. 200

TIME OF SETTING.

p initial set in not less than thirty
develop hard set in not less than one
in ten hours.

ONSTANCY OF VOLUME.

ment about three inches in diameter,
k at the centre, and tapering to a thin
t in moist air for a period of twenty-

ept in air at normal temperature and
ls for at least 28 days.

f steam, above boiling water, in a loosely for five hours.

s, to satisfactorily pass the requirements, firm and hard, and show no signs of distor- g, cracking, or disintegrating.

ULPHURIC ACID AND MAGNESIA.

nt shall not contain more than 1.75% of ulphuric acid (SO), nor more than 4% (MgO).

J. C. HAIN,
Engr. Mas. Const.

.OWETH,
gr. and Supt. B. and B.

F.

ATIONS FOR MUNICIPAL WORK AT WASHINGTON, D. C.

Dow, *Inspector of Asphalts and Cements.*

PORTLAND CEMENT.

—Not less than 95 per cent to pass a 50- and not less than 90 per cent through a 100-

etting.—Initial set, in not less than 45 minutes,

h:

until hard set, rest of day in water):

ent. . . . . 225 lbs.

ir 1 day, in water 6 days):

ent. . . . . 450 lbs.

ts sand. 175 "

air 1 day, in water 27 days):

ent. . . . . 550 lbs.

rts sand. . . . . 225 "

e neat into wedge-shaped pats about three
a side, half an inch thick at back tapering
edge, the cement must show no signs of
arping after being in air or water at normal
for 28 days.

t which shows signs of swelling after being
rejected.

must be properly seasoned; too fresh cement
nt will be rejected.

shall contain over 2 per cent of sulphuric

Portland.—Cement furnished under this
must comply with the preceding specifica-

Portland.—Cement furnished under this
must comply with the preceding specifica-
n addition must meet the following require.
s B cement is intended for special use in the

may be satisfactorily drawn within 24 hours
g a concrete made of cement one part, sand
broken stone three parts, and pebbles three
the temperature is at or above 40° Fahr., may
l as Class B cement.

e.—Each bidder must deliver at D. C.
ouse prior to time of opening proposals, a
rel of the cement which he proposes to furnish.

ge.—Portland cement delivered in wood will
in new, strong, serviceable barrels, lined
. Weight to be 400 pounds gross, and the
he cement to be not less than 375 pounds.
ement delivered in sacks will be packed in
viceable canvas sacks, containing one fourth
ntity specified to be delivered in barrel. The
e returned to the contractor or paid for at the
cents each. All sacks will be subject to in-
d approval by the Commissioners.

of delivery.—Cement will be delivered at
ehouse, located on Canal street, between Dela-
ie and First street S. W., or F. O. B. cars on
ltimore and Ohio, or Philadelphia, Baltimore
ington Railroads, at such points as may be
y the Commissioners, D. C.

—Delivery must be commenced within thirty
notice of award of contract and prosecuted at
e, not exceeding one fifth of the total amount
t in any one month, as may be ordered in

ement in arrears (or such less quantity
red) in open market, in which event
t over and above contract rates will be
he contractor in default and deducted
that may be due or may become due
t is also reserved to the Commissioners,
remedies prescribed above, to charge
ractor and deduct from any moneys
y thereafter become due, the sum of
liem (Sundays and legal holidays not
ted as liquidated and fixed damages
ractor's failure to properly perform the
act.

-Cement will be sampled after delivery.
seven-day test herein provided will be
acceptance, but the right to reject shall
any time before final payment or the
t in question. All tests will be made
prescribed by the committee of the
of Civil Engineers, with such modi-
mployed in the laboratory of the En-
nt, and which are open to the inspec-
ractors. All cements will, from time
ected to chemical analysis, and must
m any foreign substance or deleterious
the elements are combined in proper
cure the best results and insure per-
ments must be of uniform quality and
e Commissioners. The works of the

anguage to the inspector or other representative istrict or otherwise impede or embarrass him in arge of his duties shall be immediately removed ontractor, and not again employed without the of the Commissioners. Should the conduct or of the contractor require additional inspectors, be appointed and the cost thereof, not exceed- o per diem (of ten hours) for each inspector, harged against the contractor.

NATURAL CEMENT.

ess.—Not less than 95 per cent, to pass a 50- ve, and not less than 82 per cent through a 100- ve.

of setting.—Initial set, in not less than 10 nor an 30 minutes, when mixed with the smallest of water between the temperatures of 70° and .

strength:

(in air until hard set, rest of day in water):

at cement........................ 80 lbs.

s (in air 1 day, in water 6 days):

at cement........................ 150 lbs.

o parts sand....................... 80 "

ys (in air 1 day, in water 27 days):

at cement........................ 200 lbs.

vo parts sand....................... 150 "

28 days.

which shows signs of swelling after being
ejected.

ust be properly seasoned; too fresh cement
will be rejected.

hall contain over 2 per cent of sulphuric

Each bidder must deliver at D. C. Cement
time of opening proposals, a sample barrel
cement which he proposes to furnish.

-Natural hydraulic cement will be packed
ceable canvas sacks of uniform size. The
turned to the contractor or paid for at the
s each for small sacks and 10 cents for
ll sacks will be subject to inspection and
e Commissioners.

-Natural cement will be paid for at the
unds net per barrel. Each sack will con-
pounds. The contractor will be required
ent in sacks of uniform size, and bidder
ther it is proposed to furnish cement in
ks or in 150-pound sacks.

INDEX.